

# **ELECTRONIC RETAIL EFFECTS ON AIRPORTS AND REGIONAL DEVELOPMENT**

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The Academic Faculty

by

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# **ELECTRONIC RETAIL EFFECTS ON AIRPORTS AND REGIONAL DEVELOPMENT**

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## **DEDICATION**

To my parents

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## **LIST OF SYMBOLS AND ABBREVIATIONS**

3PL	Third-party logistics company
B&M	Brick-and-mortar
BTS	Bureau of Transportation Statistics
DC	Distribution center
DOT	Department of transportation
E-commerce	Electronic commerce
E-fulfillment	Electronic (retail) fulfillment
E-retail	Electronic retail
FAA	Federal Aviation Administration
FC	Fulfillment center
GDP	Gross domestic product
GRP	Gross regional product
ICT	Information and communications technology
LTL	Less than truckload
MPO	Metropolitan planning organization
OLS	Ordinary least squares
PANYNJ	Port Authority of New York and New Jersey
STIP	Statewide transportation improvement program
TIP	Transportation improvement program
TL	Truckload

## SUMMARY

This dissertation is an investigation of the relationship between e-retail logistics (e-fulfillment) and aviation, and of airport staff's planning responses to e-fulfillment. By its nature, planning requires a thorough understanding of the forces on transportation and land use that can affect areas of planning interest. Electronic retail (e-retail) is one such trend whose rapid growth influences airport activity, demand for industrial real estate, workforce needs, and surface transportation infrastructure. E-retail's growth alters regions' attractiveness for logistics development, the strategies needed to promote the industry, and the data and models required to prepare for its transportation, land use, and workforce needs. This study's objective is to provide guidance to urban and airport planners on the relevant effects on e-fulfillment as well as appropriate planning responses.

The dissertation includes a three-part analysis. A location model measures differences between the sales channels in the regional and airport traits associated with logistics activity. A survey of retail shippers is intended to examine associations detected in the logistics model and measure their relative strength by documenting differences in operations and regional needs between DCs and FCs. Interviews with logistics professionals supplement the shipper survey. Analysis 3 examines the extent to which airport staffs are planning for changes in cargo patterns associated with e-fulfillment through planning document reviews and interviews with staff at seven airports served by Amazon Prime Air.

Dissertation results indicate that e-retailers choose FC location as a function of customer proximity, airport access, integrator hub proximity, and a variety of regional

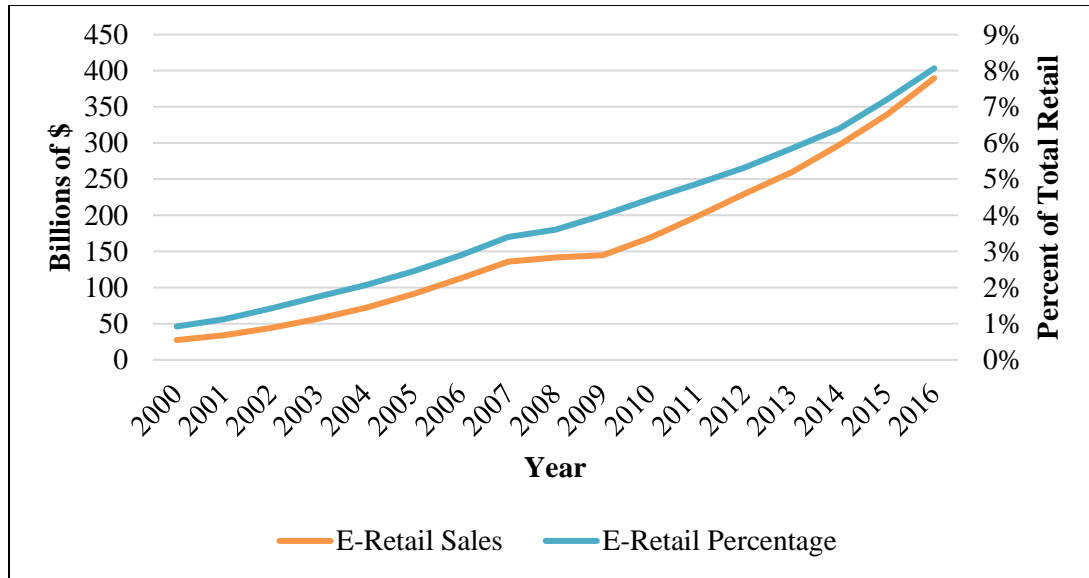
factors with weaker effects. E-retail activity will continue to generate disproportionate air cargo activity while concentrating logistics facilities in the same regions as large customer bases, integrator air hubs, and international gateway airports. These patterns will impact infrastructure and land needs, and planners should incorporate these trends into their forecasts and strategies. Airport planners are increasingly aware of e-retail's cargo generation potential, and they are gathering data in an ad hoc manner to understand it.

The dissertation concludes with a discussion of implications of the research for airport and transportation planners, economic development planners, and land use planners. Logistics activity related to e-retail is expected to grow in coming decades, concentrating particularly around logistics hubs and population centers in the Northeast, Ohio River Valley, and major metropolitan areas.

# **CHAPTER 1. INTRODUCTION**

## **1.1 Problem Statement**

Electronic retail (e-retail) is arguably the most consequential force reshaping retail logistics. E-retail is rapidly approaching 10% of U.S. retail market share, up from less than 3% a decade ago (U.S. Census Bureau 2016), and the growth trend resembles the early stages of an exponential curve, foreshadowing very high future e-retail market share (Figure 1). E-retail market share for some product types, such as books, music, and videos has already surpassed 50%, and the e-retail sales channel is approaching parity in other product types like consumer electronics and sporting goods (Torry and Stevens 2017). Moreover, as new cohorts of consumers that grew up with the internet represent a larger part of the total consumer base, their comfort with computers and smart phones is further multiplying e-retail's market share. E-retail has reached sufficient size to impact macro-economic indicators, for example depressing inflation rates by providing consumers with greater price visibility among competitors and inhibiting retailers' ability to raise prices (Torry and Stevens 2017). E-retail will be a growing force in the consumer economy for the foreseeable future, so scholars of cities and urban policymakers should understand how it affects transportation, the built environment, and regional economies.



**Figure 1. E-retail growth (annual sales, USA).**

**Source: U.S. Census Bureau (2016)**

E-retail fundamentally reconfigures retail logistics networks to meet different requirements from B&M retail logistics. Today's dominant e-retailers distinguish themselves by building fulfillment networks that permit rapid delivery of small orders while maintaining low transportation and inventory costs. B&M distribution networks need to provide large quantities of a predictable set of goods to fixed store locations with at least several days' lead time. B&M retailers must transport items to a store that is conveniently located for potential customers, and they must maintain an in-store inventory large enough to supply uncertain demand. By contrast, e-retail usually requires that small shipments be made to locations that are not known in advance (i.e., customer homes or businesses) on short notice and with low customer tolerance for error. This radically different set of requirements necessitates a logistics network with a different form from B&M retail distribution networks. Distribution centers (DCs) refer to warehouses that hold inventory

and ship products to B&M retail stores, while fulfillment centers (FCs) refer to facilities that hold inventory and process orders received through the e-retail sales channel. A single retailer may have many DCs or FCs depending on its size, geographic scope, and logistics strategy.

Airports and e-retailers influence each other even though the patterns and dynamics of their relationships have barely been explored. As evidence of their relationship, Amazon—America’s largest e-retailer—recently commissioned several cargo airlines to operate a fleet of wide-body cargo aircraft among its sortation centers and FCs, even as integrators and USPS continue to transport Amazon deliveries by air and ground (Amazon.com 2014). A report by the Airport Cooperative Research Program (ACRP) identifies e-commerce (which includes business-to-consumer e-retail) as one of the four main drivers of air freight growth, along with such notable trends as globalization, lean inventory strategies, and economic growth (Maynard et al. 2015). Firms always prefer cheaper surface transportation over air transport, which serves to overcome constraints that would otherwise preclude on-time delivery, such as late order receipt, stockouts, or errors. E-retail’s urgency and unpredictability produce more occasions when air transport is necessary to maintain delivery schedules. E-retailers can often financially justify air transport for unexpected medium- to long-distance deliveries of moderately valuable goods within a compressed delivery timeline.

E-retail’s growing market share entails shifts in the freight system, which will be reflected through a redistribution of logistics activity among regions and dramatic cargo growth at some airports (Maynard et al. 2015). While it has been remarked that integrator air hubs tend to attract logistics activity, including e-fulfillment (Kasarda and Lindsay

2011; Antipova and Ozdenerol 2013), it has been less clear the extent to which this network benefit also applies to other metropolitan areas with high consumer accessibility either through transportation networks or proximity. E-retail's potential to increase retail freight demand and change the geography of logistics activity makes e-retail important for urban and regional planning.

E-fulfillment's growth will likely affect planning practice around transportation, land use, and economic development. Reconfiguration of logistics networks can change freight origins and destinations, trip frequency, and demand for air cargo, with effects on the use of transportation infrastructure. E-fulfillment influences land use to the extent that the factors affecting location choice for logistics facilities differ among the sales channels. Employment, demand for industrial land, truck generation, and air cargo activity all derive in part from the locations of logistics facilities. Airport regions have attracted attention in the planning literature due to their ability to stimulate regional development and the high monetary stakes involved in making decisions about airport investment. Airports' future cargo activity depends in part on their place in fulfillment networks, so airport planners should explore e-fulfillment trends when forecasting cargo activity and evaluating capital projects. Yet, planning research has hardly examined the relationship between airports and e-fulfillment, or e-fulfillment's repercussions on more traditional urban planning subjects and processes.

## **1.2 Research Questions**

This dissertation asks how e-fulfillment is related to airport activity and airport-region development. Answering the research questions will reveal geographic patterns



associated with e-fulfillment, factors influencing FC location choice, differences compared with B&M retail logistics, and a state of practice for airport planning for e-retail. Three research questions, which are discussed in sequence, guide the investigation.

**Q<sub>1</sub>:** What airport and air cargo carrier traits are associated with e-fulfillment?

The first research question (Q<sub>1</sub>) asks whether airport or airport-region traits correlate with e-fulfillment activity, and whether the pattern is replicated for B&M logistics activity. Answering this question will help planners recognize whether airport regions experience disproportionate e-fulfillment activity, and factors to identify airports and regions that are likely to acquire e-fulfillment activity.

**Q<sub>2</sub>:** What dynamics might explain differences in FC and DC location?

The second research question (Q<sub>2</sub>) asks how e-retailers choose among regions for FC location as a function of their operational needs. Facility location derives from facilities' needs from their region (e.g., labor, access to transportation networks) and those facilities' role in retail logistics networks. Whereas Q<sub>1</sub> primarily searches for spatial correlations, Q<sub>2</sub> explores the operationally derived causes of those correlations from e-retailers' perspective.

**Q<sub>3</sub>:** How are airport planners preparing for e-retail cargo?

The third research question (Q<sub>3</sub>) examines how staff at airports near FCs or large consumer markets perceive e-fulfillment's effects on their operations and how they are preparing for e-retail air cargo. The answer must also categorize approaches and data sources for cargo planning in a macro context of e-retail growth. The third question

assumes airport planners' perspective to delineate a state of practice around airport planning for e-fulfillment. Answering Q<sub>3</sub> reveals opportunities for incorporating e-fulfillment trends into airport planning, including goal definition, forecasting, stakeholder involvement, alternatives evaluation, and land development.

### **1.3 Study Objectives**

The dissertation's purpose is to improve transportation and urban planning research and practice by incorporating knowledge from disciplines that affect regional development and freight generation. Therefore, the dissertation's objectives relate to the interactions between e-fulfillment and areas of interest to public-sector planners. The following subsections discuss the four primary objectives.

#### **Objective 1) Investigate e-fulfillment's relationship with transportation infrastructure and geography.**

Researchers have long treated logistics as a suitable industry for airport-centric development (Antipova and Ozdenerol 2013; Kasarda and Lindsay 2011; Güller and Güller 2003; Schaafsma, Amkreutz, and Güller 2008; Cox 2010). Airport-centric development models have rarely been tested empirically, and researchers have not observed e-fulfillment activity patterns to assess the models' transferability to e-fulfillment (Antipova and Ozdenerol 2013; Menon 2013; Verboon and Braun 2010). This dissertation provides the first known large-scale analysis of FC location in relation to airport accessibility and regional traits. The results reveal divergences between the retail sales channels regarding the factors affecting logistics facility location. The results will help planners recognize

regions that are attractive for e-fulfillment activity, with effects on cargo generation, demand for industrial land, and workforce needs.

**Objective 2) Explore patterns in e-fulfillment transportation affecting location choice.**

E-fulfillment networks are designed to serve fast, small, unpredictable, and fragmented shipments, which means that e-retailers' transportation needs differ from those of traditional B&M retailers. Researchers have studied e-fulfillment strategies (Golicic et al. 2002; Ghezzi, Mangiaracina, and Perego 2012; Cachon and Terwiesch 2009) and location choice of general-purpose warehouses (Sivitanidou 1996; Woudsma et al. 2008; Jakubicek and Woudsma 2011; Cidell 2010; Bowen 2008; Allen, Browne, and Cherrett 2012). The literature has not included comprehensive examination of transportation differences associated with the two major retail sales channels in a way that geographically addresses their freight generation potential. The differences between e-fulfillment and B&M retail logistics explain spatial patterns and predict trends as the industry matures. Therefore, the dissertation seeks to identify and weight the regional and airport factors that influence FC and DC operations and location.

**Objective 3) Document a state of practice in airport planning for e-fulfillment**

Airport leaders make capital investment decisions according to planners' demand forecasts and project evaluations. Optimizing investment requires airport planners to accurately understand the factors generating cargo and those factors' evolution over time. There are currently no scholarly articles addressing airport planning practice for e-fulfillment. Without a state of practice, airport planners encounter difficulty benchmarking

their planning efforts for e-fulfillment with leaders in the field. A dissertation objective is to record the state of practice and encourage conversation at airports about e-retail's impacts and planning responses.

**Objective 4) Create a dataset of logistics facilities for studying e-fulfillment.**

Lack of data has remained a great obstacle to planners understanding development and transportation patterns deriving from e-fulfillment. National freight and economic datasets do not distinguish retail-related logistics from other types of logistics, much less FCs and DCs from general warehousing. Inadequate data has forestalled analysis of e-fulfillment's transportation and regional development patterns. In this dissertation, private datasets are analyzed and expanded to identify FCs in the contiguous United States, which are shipment origins and sites of warehouse employment. Assembling this dataset facilitates future studies.

**1.4 Expected Contribution to Planning Theory and Practice**

This dissertation enriches planning practice in four professional specialties: transportation planning, airport planning, land use planning, and economic development planning. Strictly speaking, airports are within the professional domain of transportation planners. Nonetheless, airport planning has specific knowledge requirements related to aircraft operations, institutions, and funding that make it a very distinct specialization within the transportation field. The following four subsections explain the dissertation's contribution to these specialties.

#### *1.4.1 Transportation Planning*

Freight planners use historical data to forecast freight demand. Only a few very advanced freight demand models incorporate logistics decision making and sales channels into forecasts (e.g., supply chain models). E-fulfillment's underrepresentation in existing datasets prevents travel demand forecasts from being sensitive to e-retail trends. DCs and FCs anchor truck movements for the lifetime of a facility, which gives the facilities a long-term role in truck movement. If FCs exhibit location patterns different from those of DCs, then the differences reflect in the movement patterns of trucks serving the facilities. This study identifies regional factors guiding FC location so that freight planners can recognize where e-retail is likely to change freight patterns. It will help transportation planners predict origins, destinations, and routes of vehicles transporting e-retail goods.

#### *1.4.2 Airport Planning*

This dissertation links e-retail air cargo with airport and regional traits to help airport planners forecast air cargo and prioritize projects. E-retail reconfigures air cargo demand in ways that cannot be foreseen from trend extrapolation. While the dissertation makes contributions to four planning specialties, its largest contribution is to the field of airport planning. Airport planners have heretofore lacked peer benchmarks to guide their analysis and preparation for e-fulfillment. Specifically, the dissertation provides guidance to airport planners focusing on the first three stages of the rational planning model. Related to step 1 (define the objective), it describes airport staffs' perception of e-retail influence on airport cargo activity and the extent to which shipper data corroborate their perception. Regarding step 2 (identification of alternatives), approaches are explained for airport staff

to gather data on e-retail air cargo and to pair that data with suitable forecasting methods. For step 3 (evaluation of alternatives), airport staffs' consideration of e-retail in plan evaluation is characterized. Finally, extensive guidance is provided for regional development impacts around airports. The result is a state of practice and analysis of shipper preference with which airport planners can benchmark and guide their work.

#### *1.4.3 Land Use Planning*

Land use planners avoid conflicts among uses and provide service infrastructure for adequate developable land. Fulfilling this mission requires land use planners to estimate future demand for logistics land and identify suitable locations within the region. E-retail alters the demand for logistics land by changing retail logistics facilities' missions. E-retail's growth changes the amount or location of land that retailers seek for warehouses. Some regions may lose demand for industrial land compared with previous forecasts, while other regions or parts of regions may become more attractive. Past land use models require recalibration to update land use plans and zoning maps. The dissertation directly studies patterns of retail warehouse location and the factors that may motivate location choice. The study results can help land use planners identify their region's attractiveness to e-fulfillment activity and estimate regional land use needs. Land use planners working on comprehensive plans or zoning ordinances can inform their work with these results.

#### *1.4.4 Economic Development Planning*

Many economic development planners rightly view airports as major forces driving regional economic development, a view that airport-centric development models such as the Aerotropolis have promoted. Nonetheless, past airport-centric development modes do

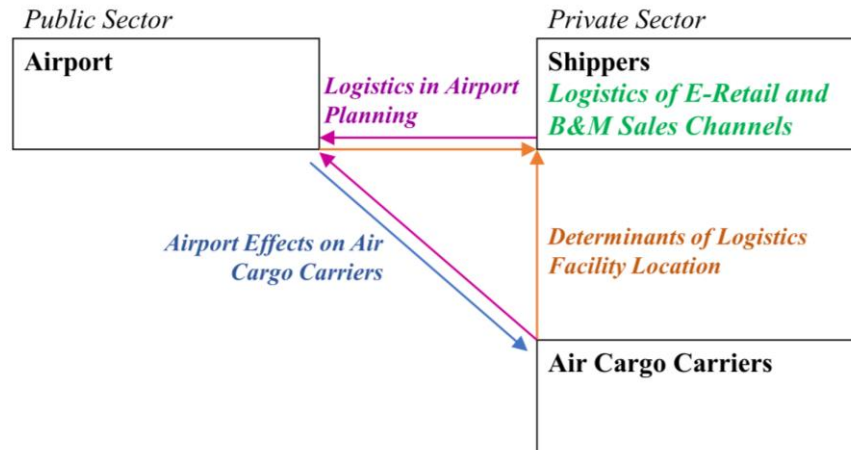
not explicitly consider e-fulfillment in determining applicability, calibrating predictions, or tailoring recommendations. Without observing patterns of e-fulfillment activity and understanding the operational factors that influence location choices, it is difficult for economic development planners to adapt airport-centric development models to this fast-growing activity. The dissertation results will help economic development planners evaluate regions' suitability for e-fulfillment based on regional traits that facilitate e-fulfillment.

## **CHAPTER 2. LITERATURE REVIEW**

### **2.1 Introduction**

The literature review is organized into two broad sections. The first section examines regional development theory and observation. It summarizes major theories of regional development that explain firm location and regional concentrations of logistics activity. It also explains patterns in national warehouse activity, which serves as a baseline for examining retail logistics locations. The second section examines the relationship between airports and e-fulfillment, in terms of both the direct relationship and the indirect relationship mediated by air carriers, as depicted through four interactions among retail shippers, carriers, and airports in Figure 2. The first dynamic relates to the forces motivating the growth and configuration of e-fulfillment. The second dynamic pertains to the factors influencing DC and FC location, especially relating to the influence of airports and air carrier networks. The third dynamic involves air carriers' selection of hub airports, which makes up part of the indirect relationship from airports to shippers via carriers. The fourth dynamic relates to the ways in which airport planners consider cargo or seek to attract shippers.





**Figure 2. Dynamics in the relationship between e-fulfillment and airports.**

## **2.2 Regional Development Theory**

Patterns of growth and development are core interests of urban and regional planners. The logistics industry affects these core interests as manifested in employment, transportation and land use. Regional development theory is the study of patterns, disparities, and causes of spatial development. The theory has evolved in waves drawing on economic theories, some of which are inherently spatial and some of which were adapted to answer spatial questions. The combination of theories with their own sets of assumptions produces a rich literature that in aggregate describes different aspects of firm location.

Each word in the phrase “regional development theory” merits definition. Region is defined variedly as a hierarchy of cities (Christaller 1933; Losch 1954), a “spatially interdependent” labor market (Dawkins 2003), or a geographic area circumscribed by administrative or ecological boundaries. Most boundaries following from the different definitions do not overlap. A logical definition for the purposes of the dissertation on

airport-centric development is a hierarchy of cities served by a common airport. This definition conforms with the two conditions set by Hoover and Giarratani (1971), which require that regions with a spatially interdependent labor market be (a) functionally integrated such that their labor, capital, and commodity flows have more characteristics in common within the region than without, and (b) that the region be oriented towards a single, dominant node. The definition delimits the region spatially by commute distance and mimics consumer market areas (Dawkins 2003). Development refers to reconfiguration of economic structures through innovation that introduces new sociocultural and economic paradigms (Friedmann 1967). Regional development therefore refers to a hierarchy of cities around an airport that have adopted the most recent trends and economic forms, in this case related to e-fulfillment.

In this section, major components of regional development theory affecting logistics are compiled. The most pertinent theories to the dissertation topic are highlighted, including Neoclassical Economic Theory and associated theories, Export Base Theory, and the New Economic Geography. Many theories are complementary, addressing similar concepts in different forms. They are not competing theories in the sense that only one can be correct while others are wrong. Instead, they describe economic development within a certain set of assumptions that are more or less useful depending on the circumstances.

Neoclassical Economic Theory addresses the ways in which market signals of supply and demand lead rational economic actors to maximize utility. Neoclassical Theories were adapted to address spatial disparities. Each region possesses a set of factor endowments that make it most suitable for select economic activities. As a function of those factor endowments, regions perform some functions more efficiently than other

regions, leading them to spontaneously specialize while trading to obtain other products or services (Ohlin 1967; Heckscher 1919). Neoclassical models predict both a convergence in the price of factors of production among regions, and regions' specialization in the industries that use their most plentiful factors of production.

Central Place Theory describes cities' size and distribution in space as a function of industries' market area, which is the land area over which firms conduct business (Losch 1954). The size of urban areas derives from the relative magnitude of transportation costs and economies of scale. Firms cluster around a market when transportation costs to market and scale economies are high, and firms disperse when transportation costs to market and scale economies are low. Central places emerge where market areas for multiple industries overlap. These central places are hierarchically organized based on their spatial extent (Losch 1954; Christaller 1933; Dawkins 2003).

Location Theory expanded on early neoclassical theories' relative neglect of space while incorporating questions of market area from Central Place Theory (Dawkins 2003). Location theorists sought to explain firm location as a function of the relative transportation costs of raw materials and final products. Firms seek to minimize transportation costs by locating at an optimal point between raw materials or consumer markets (Weber, Friedrich, and others 1929). Firms locate near raw materials when the cost to transport raw materials is high due to their weight or bulkiness, and firms locate near markets when transport of finished products is more costly than transport of raw materials (Alonso 1975).

Agglomeration economies are efficiencies that accrue to firms from proximity to other firms. In addition to a desire to be near markets (described in Central Place Theory)

and a need for proximity to suppliers or customers (described in Location Theory), Agglomeration economies induce firms of the same or different industries to locate near each other. Agglomeration economies include localization economies, which are efficiencies generated among firms of the same industry, and urbanization economies, which are efficiencies generated among firms of different industries (Hoover 1937; Perloff et al. 1960; Döring and Schnellenbach 2006). Together they can be called agglomeration economies or external scale economies. Industries' propensity to experience agglomeration economies varies as a function of their innovation, and their relationships with labor and suppliers. Three main forces generate agglomeration economies: knowledge spillovers, labor market pooling, and input sharing (Brown and Rigby 2009; Marshall 1890; Freeman 1979; Puga 2010). Knowledge spillovers occur when firms gain knowledge from firms located near them that increases their competitiveness (Döring and Schnellenbach 2006). Labor market pooling helps firms find skilled workers through large labor pools serving a regionally concentrated industry. Finally, input sharing occurs as firms in the same region develop an ecosystem of suppliers from which new entrants in the same region can purchase supplies. Input sharing decreases transportation costs from the supplier to the firm (Brown and Rigby 2009). For logistics firms, relevant agglomeration economies can reduce cost and improve service by sharing markets for labor, transportation, and warehousing (van den Heuvel et al. 2012; Cruijssen, Dullaert, and Joro 2010). There also exist agglomeration diseconomies like congestion and high land prices bid up by market competition (Tabuchi 1998; Perloff et al. 1960). When external economies outweigh external diseconomies, firms and workers in agglomerations of economic activity become more competitive, productive, and efficient than those outside. Agglomeration economies

enhance logistics firms' operational efficiency and effectiveness (Pettersson and Näversten 2012; Sheffi 2010, 2013). If agglomeration economies outweigh diseconomies, firms tend to cluster geographically. Logistics clusters may increase firms' competitiveness (Rivera, Sheffi, and Welsch 2014), although their effects appear to degrade quickly over space (Hylton and Ross 2018).

Export Base Theory explains regions' growth as a function of exports in exchange for capital. Base sectors are those whose products or services that can be exported, whereas non-base sectors primarily serve the internal regional market. Regions develop by exporting products and services from their base sectors (North 1955), because exports allow a region to accumulate capital for internal development (North 1955; Perloff et al. 1960).

Cumulative Causation Theory explains why regions retain and grow the industries that are already specialties. Cumulative Causation Theory predicts that the regions that originate economic activity retain and grow that activity, outstripping later-starting regions. The first-mover regions gain advantages related to external economies that make their factor inputs more productive and can outweigh less developed regions' lower labor costs for attracting new firms and growing existing firms (Myrdal 1957). Productive regions tend to retain and increase their advantage (Kaldor 1970).

New Economic Geography recalls Neoclassical Theories' interest in market-mediated supply and demand (Fujita and Krugman 2003). The theory "incorporate[s] external scale economies and increasing returns into traditional models of interregional trade" (Dawkins 2003). New Economic Geography explains the emergence of industrial

clusters “due to a combination of centrifugal and centripetal forces” (Dawkins 2003). Specifically, high economies to scale promote firm clustering, while high transportation costs disperse firms to locations near markets. Simultaneously, New Economic Geography incorporates a sort of cumulative causation to explain why industry agglomerations grow and retain their leading position. As small industry agglomerations attract new firms, they cement their position as a center of that industry in the country. Agglomeration economies make it advantageous for firms to continue conducting business in the region (Fujita and Krugman 2003). Even if the attribute that originally caused the industry to begin in that location disappears, the region will continue to be a center for that industry because of the agglomeration economies and labor markets that have developed since (Krugman 1991).

### **2.3 Geography of Logistics Activity**

American warehousing has decentralized and suburbanized over time. Traditionally, logistics activity concentrated in urban cores. As regions grew in population and spatial extent, logistics activity suburbanized faster than development as a whole (Dablanc and Ross 2012). In most large U.S. metropolitan areas, the logistics industry has suburbanized even while leaving the regional core logistics market intact and growing (Cidell 2010). Logistics suburbanization has also been observed in France, the United Kingdom, and Japan (Dablanc and Rakotonarivo 2010; Sakai, Kawamura, and Hyodo 2015; Allen, Browne, and Cherrett 2012).

Logistics consolidation has occurred in tandem with suburbanization, due in part to firm-level inventory consolidation. Logistics consolidation refers to the process by which warehouses serving multiple firms cluster in space. Low fuel prices have allowed firms to

combine inventory into fewer and larger facilities and still maintain moderate transportation costs (McKinnon 2009), which has produced industry-wide consolidation (Dablanc and Ross 2012; Savy 2006). Regions differ in how the trends of suburbanization and consolidation manifest. For example, Los Angeles exhibits much greater sprawl than Seattle for reasons that may relate to local transportation, land use patterns, or growth management policies (Dablanc, Ogilvie, and Goodchild 2014). Locally, the twin trends of suburbanization and consolidation have contributed to the growth of peripheral cities where logistics is one of the major economic activities of an undiversified economic base (Dablanc 2014).

Many reasons have been suggested for logistics suburbanization. As facility size has increased, logistics companies have sought cheaper land and larger, newer facilities on the periphery (McKinnon 2009). Competitive pressures of a commodified real estate market have pushed developers to build large and specialized distribution complexes often on peripheries (Hesse 2004). Airport and highway access have also driven facility location towards the peripheries where airports are typically located and peripheral highways are less congested than in urban cores (Bowen 2008). Some central cities have zoning regulations or tax rates that discourage logistics (Dablanc and Ross 2012).

Suburbanization and decentralization are trends that operate regionally. At the national level, there has been a shift away from coastal gateways towards inland ports, which may be less congested or expensive (Cidell 2010). As containerization progressively replaced breakbulk shipments, it realized productivity gains that made the transfer of cargo at seaports less costly and delay-prone. Containerization allowed items to be offloaded

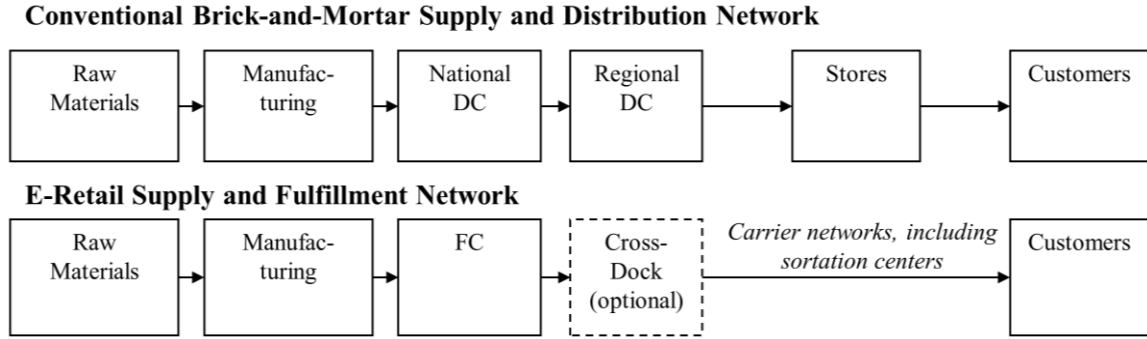
from ships and transferred directly to inland warehouses, bypassing older coastal warehouses (Rodrigue and Notteboom 2009).

## **2.4 e-Fulfillment Networks**

Sales channels refer to the means by which customers buy goods from retailers. Traditionally, purchasing retail goods required the buyer to travel to a store, select items, exchange money, take possession of the items, and transport them to their home or business. The traditional method is referred to as the “brick-and-mortar” (B&M) sales channel because purchases occur in physical stores. Electronic retail (e-retail) is a competing sales channel that separates purchase from goods’ physical transfer to the buyer. E-retail allows customers to select items to purchase at a distance through an internet portal and to take physical possession later, most often with later home delivery.

The sales channel has implications for the retailers’ logistics network. The separation of purchase and transfer allows the e-retail supply chain to omit several steps from the brick-and-mortar supply chain (Figure 3). Stores are no longer necessary for e-retail. Instead, retailers rely more heavily on warehouses called fulfillment centers (FC) to deliver directly to customers. FCs are normally located to minimize costs, maximize market access, and meet delivery schedules. E-retailers trade off transportation costs, which are lower in a dispersed network, and inventory costs, which are lower in a centralized network.





**Figure 3. Logistics networks for B&M retail (top) and e-retail (bottom).**

**Source: Derived from Hesse (2002)**

E-retail alters core distribution assumptions and relationships (Golicic et al. 2002). Multiple researchers have suggested that FCs cluster more tightly around airports than DCs. E-retail encourages inventory pooling (Cachon & Terwiesch, 2009), which modifies optimal inventory location and consolidation. FCs tend to become larger and fewer compared with DCs as inventory consolidates (Mangiaracina et al. 2015; Sui and Rejeski 2002). Since transportation costs and speed restrain the amount of inventory consolidation that is feasible, air delivery may be needed to serve distant customers (Mangiaracina et al. 2015; Romm 2002). FCs may locate closer to airports than DCs since e-retailers frequently employ integrators, whose networks center on several hub regions (Kasarda and Lindsay 2011). Moreover, e-retail generates more overnight deliveries than B&M retail (Mangiaracina et al. 2015). E-retail will likely increase the distance and frequency of deliveries, and expand truck and air cargo usage (Hesse 2002).

Product characteristics also affect the configuration of e-fulfillment networks. Higher-value commodities can support greater inventory consolidation because higher sales price mitigates transportation costs. On the other hand, low-value products like

groceries are only feasible in e-retail if transportation and inventory costs remain low (Agatz, Fleischmann, and Van Nunen 2008). The easiest products to sell through e-retail are non-tangible products such as books and DVDs (Rotem-Mindali and Weltevreden 2013), and the range of products that can be effectively sold through e-retail is expanding to tangible, personal items like clothes, shoes, jewelry, and cars. Consumer electronics, shoes, and apparel make up over half of e-retail sales excluding travel, entertainment, and financial products (IATA 2017). Non-standard and perishable products such as groceries have very low e-retail market share.

The delineation in logistics networks between B&M retail and e-retail is fluid. Omni-channel logistics is common, even among retailers that generate most sales through stores. B&M retailers who commence e-retail operations must decide whether to fulfill orders from a new set of dedicated FCs, from existing DCs, or from stores (Agatz, Fleischmann, and Van Nunen 2008). Shippers' networks dovetail with carriers and logistics service providers. For instance, retailers may also outsource warehousing or distribution to a company that provides logistics services to multiple companies, called a third-party logistics provider (3PL) (Rabinovich, Knemeyer, and Mayer 2007; Makukha and Gray 2004). The major advantages of a 3PL are flexibility, expertise, and economies of scale (Gong and Kan 2013; Hesse 2002). Concretely, 3PLs can permit the consolidation of inventory from multiple firms in a single warehouse or of shipments in a single vehicle or within a single carrier contract. Shippers' logistics networks also operate in tandem with carriers' own transportation networks, including integrators, USPS, 3PLs, and others. Carriers operate not only vehicles but also warehouses for short-term inventory storage and sortation centers to facilitate transfers and routing (Bowen 2012; Barnhart and Shen 2004).

Thus, changes in shipper strategies and logistics networks ripple through downstream providers. The overlap of networks serving shippers and logistics service providers in geographic space results in a regionally combined logistics ecosystem.

Consumers have different levels of influence on the forms of e-fulfillment networks because their buying patterns differ. Frequent online shoppers have an outsized role in the formation of e-fulfillment networks compared with the population at large. In the early days of e-retail, online shoppers were highly differentiated from non-online shoppers, including by age (younger than non-online shoppers), gender (predominantly male), income (higher-income) and personality (low risk aversion and high convenience-seeking behavior) (Donthu and Garcia 1999; Brashear et al. 2009). While there are still many distinctions between online shoppers and non-online shoppers, there has been a heterogenization of buyers as e-retail's market share has grown, meaning that many buyers with divergent traits have entered the market (Agudo-Peregrina, Hernández-García, and Acquila-Natale 2016). There is no longer a meaningful distinction by gender in the pool of online shoppers, and distinctions by income and age have shrunk (Brashear et al. 2009; Agudo-Peregrina, Hernández-García, and Acquila-Natale 2016). There are simply many more customers with different characteristics in the market than there were in the past. Nonetheless, the average online shopper is younger and of higher income than the population as a whole, while also exhibiting lower risk aversion and greater convenience-seeking behavior (Smith 2015).

E-fulfillment networks are assuming new configurations that theory has not incorporated. Amazon, America's largest e-retailer, provides several examples, from aerial drones to dedicated delivery trucks, lockers for customers collecting purchases, and

grocery delivery (Manjoo 2016; Gillon 2016; Amazon Fresh 2014; D’Onfro 2014). One of its most original decisions has been to contract with three air carriers to operate over two dozen dedicated aircraft for domestic air cargo to rebalance inventories among its FCs (Greene and Gates 2015; Jamerson 2016).

## **2.5 Determinants of FC Location**

Each retailer builds its logistics network based on its needs and strategy. When retailers are aggregated by sales channel, trends emerge about the ways in which transportation infrastructure, networks, and regional traits influence warehouse location choice. Several approaches have been used to identify factors that help determine warehouse location. One approach uses firm-level interviews and case studies to describe the strategies that drive warehouse location and transportation mode choice (Sui and Rejeski 2002; Ghezzi, Mangiaracina, and Perego 2012; Lasserre 2004). A second approach is optimization, which provides detailed recommendations for facility location based on inputs about the firm (e.g., transportation cost, product characteristics, and customer and supplier locations). Optimization can guide decision making about the form of e-fulfillment networks (Fan et al. 2015; Liu 2014). The third approach, which most directly relates to this dissertation, is observation and description of warehouse locations. The third approach may involve statistics to correlate location with regional traits or surveys to assess manager preferences. The remainder of this section describes the third approach.

Airport access is positively associated with multiple types of logistics activity (Antipova and Ozdenerol 2013; Appold 2013; Jakubicek and Woudsma 2011; Karsner 1997; Verboon and Braun 2010; Woudsma et al. 2008; Deloitte and Metro Atlanta

Chamber 2017). Higher warehouse rents near airports attest to many logistics firms' preference for near-airport locations (Sivitanidou 1996). Warehousing tends to follow air activity to a new airport when one is built (Karsner 1997). The logistics firms most strongly attracted to airports require fast transportation (Brueckner 2003). Airports affect other industries as well, making many types of firms more productive (Fullerton, Licerio, and Wangmo 2010) and raising regional employment (Cidell 2015; Yan and Yuan 2011).

Airports change the geography of logistics development among regions as well as within them. The presence of commercial airports stimulates a region's logistics industry more than do new roads (Cidell and Adams 2001; Cidell 2010). Airports attract increasing numbers of logistics firms to the region as their connectivity increases (Appold 2013) and costs associated with air movement decline (e.g., congestion, regulations). Additional airport factors that may affect regional logistics activity include airspace congestion, airport spending, runway length, operational restrictions, and cargo hub status (Cui et al. 2013; Nunn 2005).

Many other regional factors influence warehouse location. Highways attract warehouses by providing connectivity (Woudsma et al. 2008; Cidell 2010; Sivitanidou 1996; Deloitte and Metro Atlanta Chamber 2017), while roadway congestion deters warehouses (Warffemius 2007a). Railroads have a smaller effect on logistics location than either airports or highways, although railroad access and intermodal facilities attract DCs (Jakubicek and Woudsma 2011; Bowen 2008). Seaports attract warehouses as well (Jakubicek and Woudsma 2011; Bowen 2008; Sivitanidou 1996; Deloitte and Metro Atlanta Chamber 2017). Warehouse managers have reported a preference to locate

facilities near transit in order to provide blue-collar workers inexpensive commute options (Jakubicek and Woudsma 2011).

Economic variables affecting warehouse location relate directly to the use of factors of production or market-based transactions. These include the availability of blue-collar labor, (Jakubicek and Woudsma 2011; Sivitanidou 1996), workforce training (Deloitte and Metro Atlanta Chamber 2017), low land costs, low tax rates (Jakubicek and Woudsma 2011), access to nearby consumers (Jakubicek and Woudsma 2011), and the absence of operational restrictions (Jakubicek and Woudsma 2011). Business-friendly environments also encourage warehousing (Deloitte and Metro Atlanta Chamber 2017). Agglomeration economies promote regional warehousing and prompt managers of warehouses in agglomerations to maintain their facilities' location in the agglomeration (Warffemius 2007b).

Site-specific variables influence warehouse location choice. Regional facilities normally require large floor areas (Sivitanidou 1996), and distributors prefer sites with new buildings (Sivitanidou 1996) and undeveloped adjacent land for future expansion (Jakubicek and Woudsma 2011). Many characteristics absent from old warehouses are useful for modern warehouse operations, including high ceilings for stacking, mezzanines for small items or auxiliary services (e.g., packing), ample truck and trailer parking, and paved ground for vehicle staging (Jakubicek and Woudsma 2011; Sivitanidou 1996). Table 1 below summarizes transportation, economic, and site-specific factors that affect warehouse location.

**Table 1. Factors affecting warehouse location.**

<b>Factor</b>	<b>Positive Effect</b>	<b>Author(s)</b>
<b>TRANSPORTATION VARIABLES</b>		
Congestion	Less congestion	Warffemius (2007b)
Airport Proximity	Shorter distance	Alkaabi, Debbage, and Touq (2013), Bowen (2008), Jakubicek and Woudsma (2011), and Sivitanidou (1996)
Airport Access	Better access	Woudsma et al. (2008)
Highway Access	Better access	Woudsma et al. (2008)
Highway Miles	More miles	Cidell (2010), Sivitanidou (1996)
Rail Access	Better access	Bowen (2008)
Rail Intermodal Facilities	Better access	Jakubicek and Woudsma (2011)
Seaport Proximity	Shorter distance	Jakubicek and Woudsma (2011)
Seaport Access	Better access	Bowen (2008), Sivitanidou (1996)
Public Transit	Better availability	Jakubicek and Woudsma (2011)
<b>ECONOMIC VARIABLES</b>		
Economies of Agglomeration	More economies of agglomeration	Warffemius (2007b)
Local Blue-Collar Labor Pool	More workers	Jakubicek and Woudsma (2011), Sivitanidou (1996)
Land Costs / Tax Rates	Lower costs	Jakubicek and Woudsma (2011)
Access to Customers	Lower distance to customers	Jakubicek and Woudsma (2011)
Regulations / Operations Restrictions	Fewer regulations / restrictions	Jakubicek and Woudsma (2011)
<b>SITE-SPECIFIC VARIABLES</b>		
Buildings Matching State-of-the-Art Operational Needs (e.g., size, height, trailer parking, truck staging area)	Better needs alignment	Jakubicek and Woudsma (2011), Sivitanidou (1996)
Building footprint	Large footprints needed for regional facilities	Sivitanidou (1996)
Building Age	Newer building	Sivitanidou (1996)
Land Available for Expansion	More land	Jakubicek and Woudsma (2011)

There has been little quantitative work addressing how air cargo connectivity affects warehouse location. Results of qualitative studies have shown that regions with better-connected airports attract some categories of logistics activity. For example, Kasarda and Lindsay (2011) say that many FCs and DCs around Louisville, KY (SDF) located there primarily to access the air hub of UPS, the second largest integrator. Locating near the integrator air hub allows managers to accept orders for overnight delivery later in the afternoon and to extend the facility's working day. There have also been attempts to relate air cargo connectivity to regional economic growth (Green 2007). However, the ways in which air carrier networks shape FC and DC location has not been a subject of nuanced study. To the author's knowledge, no studies distinguish effects of air carrier networks on warehouse location by sale channel. The evidence for airports' influence on warehouse location is robust, even as air carrier effects remain exploratory.

Airport and air carrier effects on local logistics industries exhibit bidirectional causation. Logistics firms locate in part based on air connectivity at the nearby airport, and airlines respond to changes in demand by modifying their flight offerings. Bidirectional causation complicates many analyses of the relationship between air networks and logistics. Bidirectional causation has been addressed in studies of passenger travel (Allroggen and Malina 2010; Green 2007; Irwin and Kasarda 1991; Ivy, Fik, and Malecki 1995; Knippenberger 2010; Levi 2015; Neal 2012; Nunn 2005; Tittle, McCarthy, and Xiao 2013) and air cargo (Chang and Chang 2009; Yan and Yuan 2011).



## **2.6 Airport Effects on Air Cargo Carrier Networks**

Airports influence warehouse location both directly as a function of airport traits and indirectly via air carrier networks. From a shipper perspective, an airport is primarily important for the access it provides to air cargo networks. Several types of air carriers transport cargo. Passenger airlines transport cargo in the bellyholds of their aircraft, and dedicated cargo airlines or cargo aircraft operators (e.g., Cargolux and Panalpina) convey large, long-distance cargo loads aboard freighters. E-retailers interact most with a third type of carrier, called integrators (Bensinger and Stevens 2014). Integrators operate air and ground networks that can provide door-to-door delivery. National postal services also transport a considerable amount of e-retail shipments aboard their own trucks and aboard other carriers' aircraft through postal contracts. By some estimates, 70% of e-retailers worldwide transport goods by the postal service for at least some of the items' movement (van Mook 2018).

The factors that make an airport likely to develop high cargo connectivity or become a hub matter for regions because of their effect on regional economies and the logistics industry. Factors include airport traits that policymakers can influence, intrinsic regional traits, and the national context. Concerning airport traits, low user costs (e.g., landing fees, warehouse rates), high facility quality, and high service quality encourage new cargo routes (Ohashi et al. 2005). Faster cargo connections appear even more influential than costs, meaning that aeronautical fee increases that improve service and shorten connecting delays may be justified (Ohashi et al. 2005). Airports with fast customs clearance also tend to attract international origin / destination air cargo (Gardiner, Humphreys, and Ison 2005). Since next-day air cargo delivery frequently necessitates late-

night connections, airport curfews are among the most dissuasive regulations to connecting cargo growth. Other operational restrictions also discourage air cargo (Gardiner, Humphreys, and Ison 2005; Lin et al. 2005). Runway and taxiway congestion impedes improvements in cargo connectivity (Gardiner, Humphreys, and Ison 2005), while ample space for parking, aircraft movements, and terminals encourages cargo connectivity (Menon 2013). Finally, harsh weather degrades operational reliability, especially snow storms, thunderstorms, and fog. Airlines prefer to transship cargo at airports with more temperate weather conditions (Huston and Butler 1991).

Intrinsic regional and national traits can pre-dispose an airport to intensifying air cargo connectivity. Large regional manufacturing concentrations and inexpensive factors of production (e.g., labor and land), lower airspace congestion, and high ground connectivity all promote air cargo connectivity (Lee and Yang 2003; Gardiner, Humphreys, and Ison 2005; Yeo, Wang, and Chou 2013). Among national traits, high national stability (Lin et al. 2005) and centrality to freight flows (Gardiner, Humphreys, and Ison 2005; Menon 2013; Yeo, Wang, and Chou 2013) promote air cargo connectivity. Table 2 summarizes factors influencing air cargo connectivity.

**Table 2. Effects on air connectivity.**

<b>Scale</b>	<b>Variable with Effect on Air Cargo Connectivity and Hubbing</b>	<b>Direction of Effect</b>	<b>Author(s)</b>
Airport	Longer transit / transshipment time	-	Ohashi et al. (2005)
Airport	Short customs clearance time	+	Gardiner, Humphreys, and Ison (2005)
Airport	Higher cost of using airport	-	Ohashi et al. (2005)
Airport	Airport congestion (airside)	-	Gardiner et al. (2005)
Airport	Operational regulations	-	Gardiner et al. (2005), Lin et al. (2005)
Airport	Good airport infrastructure	+	Menon (2013), Yeo, Wang, and Chou (2013)
Airport	Bad weather	-	Huston and Butler (1991)
Region	Larger population	+	Huston and Butler (1991)
Region	Regional manufacturing	+	Lee and Yang (2003)
Region	Regional corporate functions	+	Lee and Yang (2003)
Region	Airspace congestion	-	Gardiner et al. (2005)
Region	Landside connectivity	+	Gardiner et al. (2005)
Region	Lower labor costs	+	Gardiner et al. (2005)
Region	High labor availability	+	Gardiner et al. (2005)
Region	Low land cost	+	Yeo et al. (2013)
National	Central geographic location	+	Gardiner et al. (2005), Menon (2013), Yeo et al. (2013)
National	National stability	+	Lin et al. (2005)

## **2.7 Logistics in Airport Planning**

The airport planning process involves the projection of cargo and passenger needs, and the selection of infrastructure, programs, and policies to meet them. Airport planning has been studied from several perspectives. A series of government and research reports provide ‘conceptual guidance to airport planners (Maynard et al. 2015; Spitz and Golaszewski 2007; Federal Aviation Administration 2015). Other literature examines limitations of the rational planning model in guiding major airport investment decisions (Goetz and Szyliowicz 1997; Burghouwt 2013). No known studies have examined e-fulfillment’s inclusion in airport planning.

### *2.7.1 E-Fulfillment in Airport Planning*

The airport planning process seeks to “provide the framework needed to guide future airport development that will cost-effectively satisfy aviation demand, while considering potential environmental and socioeconomic impacts” (Federal Aviation Administration 2015). FAA planning guidance derives from the rational planning model, composed of constituting goals, evaluating alternatives, selecting a course of action, and execution. The airport master plan outlines the airport’s short-, medium-, and long-range development goals, and establishes funding mechanisms and a schedule for implementing the goals (Federal Aviation Administration 2012). It helps the airport meet demand in ways that are environmentally, socially, and economically beneficial (Federal Aviation Administration 2015, 2). The master plan itself is not subject to FAA approval, but the FAA approves forecasts and the airport layout plan (ALP), based on which the FAA determines airports’ eligibility for federal funds (Federal Aviation Administration 2012).

Weaknesses have been revealed in airport planning because of the inability to consistently and correctly apply the rational planning model due to extreme economic, political, and social complexities involved in large infrastructure projects. For example, planning and construction of Denver International Airport (DEN) encountered many problems plaguing megaprojects, such as cost overruns, delays, and overly optimistic forecasts (Goetz and Szyliowicz 1997). Goetz and Szyliowicz (1997) believe that the rational planning model is fundamentally flawed for megaprojects. The rational planning model considers few scenarios, evaluates few alternates, uses resources inefficiently, resists inter-stakeholder collaboration, and generates conflicts among stakeholders (Wijnen, Walker, and Kwakkel 2008). To improve the rational planning model, stakeholders, particularly airlines, must be heavily involved in planning because they select the air routes and hubs that in large part determine airport activity. Responsibility for airport planning should roughly correspond with the regions affected by the airport, which is not normally a single municipality but rather a group of municipalities in a metro region. Moreover, Goetz and Szyliowicz (1997) recommend adopting flexible frameworks that emphasize hedging and corrigibility. Hedging controls for risks through backups and redundancy, while corrigibility is the ability to learn and adapt. Airport staff should develop an organizational culture that constantly monitors the conditions related to previous decisions, and they should change or adapt those decisions if needed (Goetz and Szyliowicz 1997).

Kwakkel, Walker, and Marchau (2008) propose a planning approach called Adaptive Policymaking (APM) that de-emphasizes forecasts' inevitable inaccuracies. Once airport leadership selects a policy goal, vulnerabilities to goal's achievement are

identified, immediate actions to mitigate risk are designated, and metrics for continuous risk evaluation are selected. These metrics reveal whether the original analysis is still valid or if adaptation is necessary. As metrics show conditions changing, the policies can either be adapted with defensive actions or re-examined in their entirety. APM assumes that conditions will change and protects policy goals by controlling risks and constantly examining underlying conditions (Kwakkel, Walker, and Marchau 2008).

The airport planning literature has largely omitted e-retail considerations in the planning process. Nonetheless, select airport planning researchers and professionals have recognized e-retail as one of the major forces shaping air cargo (Kauffman n.d.; King 2016; Maynard et al. 2015). Airport-centric development models are the component of the airport planning literature that has addressed e-fulfillment most extensively. ‘Airport-centric development’ is the generic name for normative paradigms such as the Aerotropolis or the Airport City that provide guidance to airport managers and local governments for the disposition of land around airports to maximize development and cargo generation. These models prescribe a spatial form for regional development around an airport and provide recommendations, often not empirically tested, for developing land in concert with the airport. If the master planning process concentrates on the airport property, then airport-centric models focus on ancillary on- and near-airport activity. They usually recommend locating functions that generate passenger or cargo demand near the airport.

Several categories of models of airport-centric development exist, each with a slightly different focus. The Global TransPark uses the airport as an a-geographic node in production networks whereby components arrive by air, are assembled on site, and transported by air as finished products to consumer markets (Kasarda 1998; Sit 2004). It is

disconnected from the region and serves global demand. The Airport City addresses airport-adjacent land for business functions such as hotels, offices, and conferences centers that generate high rents for well-connected airports (Güller and Güller 2003; Pougias 2009). The Airport Corridor derives from traffic flows between the airport and regional hubs that make the land adjacent to the transportation infrastructure propitious for activity requiring access to both the airport and regional hubs (Schaafsma, Amkreutz, and Güller 2008). Finally, the Aerotropolis is one of the most amorphous models since it encompasses all regional activity whose location or activity is influenced by the airport. It is an entire region that has reached an undefined critical mass of dependence on the airport for global connections generating economic strength (Kasarda and Lindsay 2011). The Aerotropolis therefore presents itself as encompassing other airport-centric models in its geographic scope and functions.

Airport-centric development models have established a consensus around several points. First, activities that interact most closely with airports should be most accessible to airports. Access normally entails placing support activities such as hotels, rental cars, conference centers, and freight intermodal centers near the airport, or at least easily connected to the airport by uncongested highways or frequent train service. Functions that depend on the airport less directly, including offices, warehouses, manufacturers, and residences are located slightly farther away. This hierarchy is normally assumed even when not explicitly stated. A second point of consensus is best expressed by Kasarda and Lindsay (2011), who explain that each era's urban form and regional economies are shaped by the era's dominant transportation mode, and that aviation currently dominates. A third point of consensus surrounds aviation's effects on passenger- and freight-related activity. Most of

the work focuses on passenger-related activity, which is not surprising considering that the clear majority of the world's commercial aircraft are dedicated to passenger transport. Nonetheless, most of the airport-centric development models can accommodate freight activity, and several models focus on freight and logistics. Most models omit e-retail.

Major airports around the world have created real estate divisions to administer leases and manage commercial property on the airport and near the airport (Kasarda 2008). These real estate divisions are in effect part of “complex multifunctional enterprises serving both aeronautical needs and commercial development” (Kasarda 2006). Having begun to pursue Airport City-style development in the 1980s, Amsterdam Airport Schiphol is one of the oldest examples of this development model (Freestone 2009). Schiphol Group's real estate division has even spread such multifunctional airport-centric development to airports thousands of miles from its home airport since Schiphol Group has been contracted for the management of other airports (Freestone and Baker 2011). The case of Schiphol Group is also instructive because it manages commercial and industrial sites both on airport property and near the airport, effectively competing with other real estate developers (Morrison 2009).

Airport-centric development models may conflict with recommendations to align airport master planning with regional land use policies in a way that avoids incompatibilities between airport activities and surrounding functions. To avoid incompatibilities, regional land use plans should not concentrate people or activities around airports in ways that could interfere with the airport's 24-hour operations or obstruct eventual expansion (Janic 2016).



## **2.8 Research Gaps**

In summary, e-fulfillment is rarely addressed in the literature distinctly from B&M retail logistics. However, regional determinants of facility location and airport influence on air connectivity are well defined. Associations between air connectivity and logistics are moderately well defined. E-fulfillment is documented from a strategic perspective, but no known studies have observed FC locations over a large set of companies and geographies. With the exception of the book by Kasarda and Lindsay (2011), no known studies have associated FC locations with air cargo connectivity. Finally, the airport planning literature is devoid of studies documenting the state of or possibility for incorporating considerations related to e-retail activity into airport planning (Table 3).

**Table 3. Research gaps.**

	<b>Regional Determinants of Warehouse Location</b>			<b>Airport Influence on Air Connectivity</b>	<b>Association between Air Connectivity and Logistics Activity</b>	<b>Airport Planning Process</b>
	<b>Optimization</b>	<b>Strategic</b>	<b>Empirical</b>			
<b>Not Specific to Sales Channel</b>	Beamon 1998; Erera 2000; Jauhar and Pant 2016; Lewis, Erera, and White 2006; Stadtler 2015	Woudsma et al. 2008	Alkaabi, Debbage, and Touq 2013; Antipova and Ozdenerol 2013; Appold 2013; Bowen 2008; Cidell 2010; Cidell and Adams 2001; Jakubicek and Woudsma 2011; Karsner 1997; Sivitanidou 1996; Verboon and Braun 2010; Dablan and Ross 2012	Gardiner, Humphreys, and Ison 2005; Huston and Butler 1991; Lee and Yang 2003; Menon 2013; Ohashi et al. 2005; Yeo, Wang, and Chou 2013	Appold 2013; <i>numerous for regional economics</i>	Maynard et al. 2015; Spitz and Golaszewski 2007; Burghouwt 2013; Federal Aviation Administration 2015a; Goetz and Szyliowicz 1997; Nixon 2014
<b>E-retail</b>	Fan et al. 2015; Liu 2014	Sui and Rejeski 2002; Ghezzi, Mangiaracina, and Perego 2012; Lasserre 2004	<b><u>NO NATIONAL OR EMPIRICAL STUDIES</u></b>	<i>No change</i>	Kasarda and Lindsay 2011 (case study); <b><u>NO NATIONAL STUDIES</u></b>	<b><u>NO PREVIOUS ANALYSIS</u></b>

### *2.8.1 No Previous Distinction between e-Fulfillment and B&M Retail in Warehouse Location*

Past studies have not distinguished differences between DCs' and FCs' location choice. For example, Sivitanidou (1996), Cidell (2010), Bowen (2008), and Dablane and Ross (2012), and Hylton (2014) each address aspects of warehouse location at the metropolitan or megaregion scale. The vast majority of the literature on e-retail distribution is from the perspective of a single firm (Agatz, Fleischmann, and Van Nunen 2008; Golobic et al. 2002; Marri, Irani, and Gunasekaran 2006; Matthews, Hendrickson, and Soh 2001; Ricker and Kalakota 1999). Researchers of transport geography or urban planning tend to focus on other topics such as the effect of e-retail on roads (Rotem-Mindali and Weltevreden 2013). Past studies provide valuable insights on warehouse decentralization, firm-specific warehouse location, e-retail effects on roads, and the relationship between transportation infrastructure and general warehousing. However, they do not identify differences in location choice between FCs and DCs in a generalizable way, nor designate the factors driving FC location choice.

### *2.8.2 Extent of Association between Air Connectivity and Logistics Activity*

There has been extensive work addressing the relationship between the passenger air network and regional economic activity (Green 2007; Irwin and Kasarda 1991; Ivy, Fik, and Malecki 1995; Neal 2012; Yan and Yuan 2011). However, the interaction between air cargo connectivity and economic development has been explored to a lesser extent. Green (2007) found that cargo connectivity does not spur economic growth, while Chang and Chang (2009) uncovered a reciprocal relationship between air cargo connectivity and

economic growth. Therefore, there remains much to explore in the connection between air cargo connectivity and regional economic activity, particularly logistics activity.

### *2.8.3 State of Airport Planning for e-Fulfillment*

Normative airport-centric development models such as the Aerotropolis have furnished broad recommendations for regional leaders and airport planners to realize regions' logistics potential. Normative development models assume very optimistic growth rates, which have not materialized outside of several significant hubs (Maynard et al. 2015). Furthermore, there has been no work to the author's knowledge exploring the extent to which airports are planning implicitly or explicitly for e-fulfillment. Therefore, airport planners currently have no readily available means to benchmark their cargo planning for e-fulfillment with peers.

## CHAPTER 3. CONCEPTUAL MODEL

### 3.1 Introduction

The conceptual model specifies the entities and relationships that are most important to answering the research questions. The primary relationships of the conceptual model are depicted in Figure 4 below. They make up the sides of the triangle formed by airports, retail shippers, and air carriers. Each side involves bilateral interactions as well as indirect connections via the third vertex. Macro-scale social, economic, and governmental conditions influence actions of shippers, carriers, and airports. The following paragraphs summarize these primary actors' decision making regarding the research questions, and relationships among them.

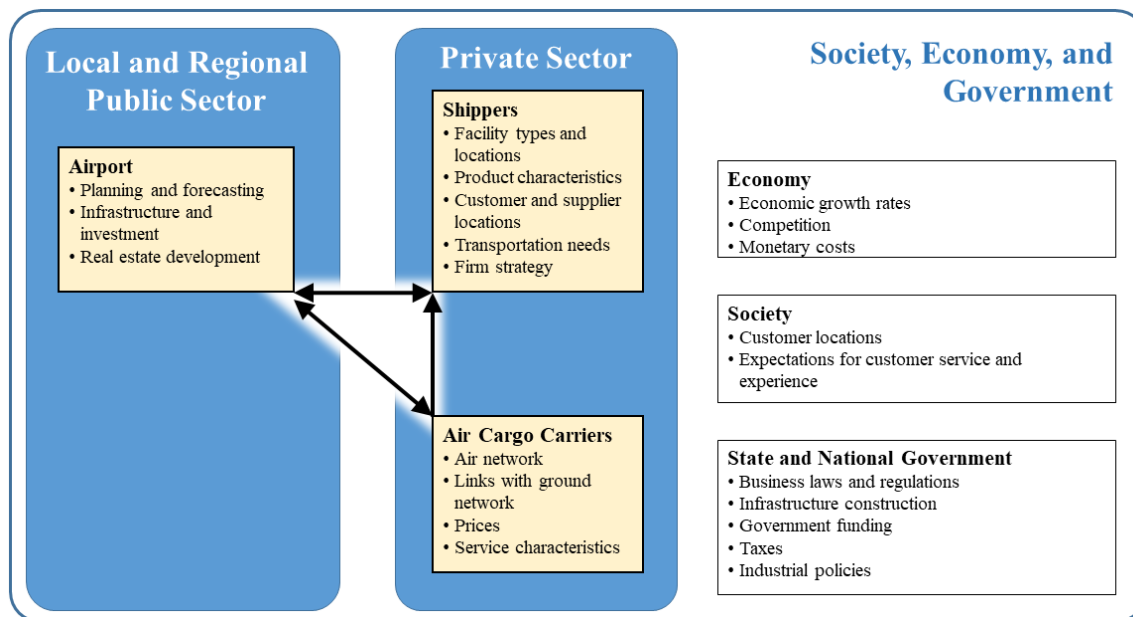


Figure 4. Conceptual framework.

Note: Primary actors highlighted.

### **3.2 Primary Actors in the Conceptual Model**

Shippers are the first vertex of the conceptual model. In this context, shippers are retailers' logistics branches or their third-party logistics managers. As a function of sales channel and logistics strategy, retailers locate warehouses to meet customer delivery requirements and maximize profits. Retailers use forecasts and models to weigh trade-offs between inventory pooling and transportation costs in logistics network construction (Simchi-Levi, Kaminski, and Simchi-Levi 2000). Warehouses spatially anchor the origin of outbound trips, durably shaping the geography of transportation demand. Retailers form their own networks as a function of retailer needs, customer expectations surrounding delivery speed, regional traits, agglomeration economies, and other factors. These individual decisions in aggregate generate industry-wide trends.

Carriers refer to the firms that physically transport goods. Retailers select transportation modes and carriers based on their inventory location, customer expectations for delivery speed, and customer willingness to pay for delivery speed and reliability. Air carriers respond to retailer demand with changes to their network. The form of air carriers' transportation networks depends on the size of demand, origin and destination locations, airport infrastructure, airport costs, and macro-scale factors like weather trends, fuel costs, national and regional labor costs, and regulations. The conceptual model concentrates on air carriers even though all carriers experience similar dynamics.

Airports' cargo activity derives from the aggregation of air carriers' networks and shipper demand. Airport staff seeks to predict and accommodate carrier demand. Airport staff can respond quickly to operational changes, but require months or years to build new

infrastructure. Airport planners forecast passenger and freight demand on a multi-decade time horizon in order to prepare necessary infrastructure, which means that they must first understand shipper and carrier trends. Airport staff is not passive regarding demand. They may seek to attract air carriers through incentives, policies, or infrastructure.

Airport staff also interacts with local and regional governments to avoid land use conflicts, to plan surface transportation infrastructure to the airport, and in some cases to promote airport-related development. Local and state transportation planners also forecast surface freight activity to evaluate surface transportation projects. Simultaneously, the existing transportation infrastructure's form, condition, cost, and congestion (resulting from past planners' work) shape carriers' networks.

### **3.3 Macro-Scale Conditions**

Airports, carriers, and shippers all make investment and operational decisions within a macro-scale context of social, economic, and legal conditions over which they have little direct influence. Macro conditions belong to three categories, which partially mirror the vertices of Porter's (1990) national-level diamond model. The categories are economic, social, and government conditions.

The economy's size, wealth, and growth influence demand for retail goods and air cargo. Economic conditions include the employment rate and income levels (affecting prosperity and purchasing power), economic growth rates (affecting expected investment returns), monetary costs, and market interest rates (affecting investment costs). The cost to finance new investment through debt derives directly from macro-economic monetary costs, which constrain investment opportunities for airports, carriers, and shippers.

Social conditions include demographics related to population trends and locations that influence demand for e-fulfillment. Social conditions also include customer expectations for level of service.

Lastly, there are numerous constraints from state and national governments. Some government constraints set hard boundaries for business activity (e.g., regulation), whereas others influence rather than dictate (e.g., taxes and spending). State and national government constraints are distinct from actions by the local and regional public sector since the latter operate within the state and national governments' constraints.

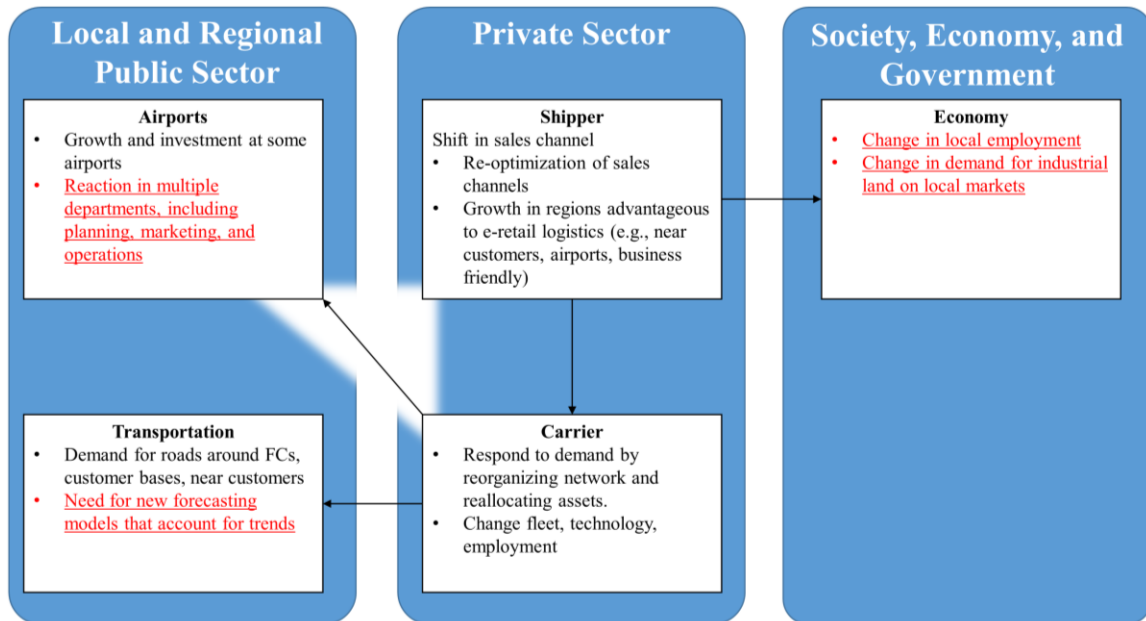
### **3.4 Planning Implications**

E-retail entails changes in customer expectations, shipper locations, and carrier networks. Reconfigured logistics networks produce new patterns of demand for warehouses. Regions that had formerly been attractive for retail logistics may become less so, and vice versa. The entire retail logistics sector may grow or shrink as a portion of the overall economy. Changes in warehouse demand affect logistics employment's scale and location, which is of interest to economic development planners, and demand for industrial land, which matters to land use planners.

The second effect of the reconfiguration of retail logistics is on freight movement. As e-retail changes freight origins and destinations, it will impel carriers to update their networks. Carriers can typically respond quickly to changes in demand by reshuffling their timetables. Carrier's reconfiguration affects planning because transportation planners are concerned with airports and surface transportation infrastructure. As carriers reconfigure their networks, airport activity changes as a function of the airport's place in those networks



and other regional traits. Demand for trucking activity changes in similar ways. Figure 5 overlays planning impacts on the conceptual model.



**Figure 5. Planning implications.**

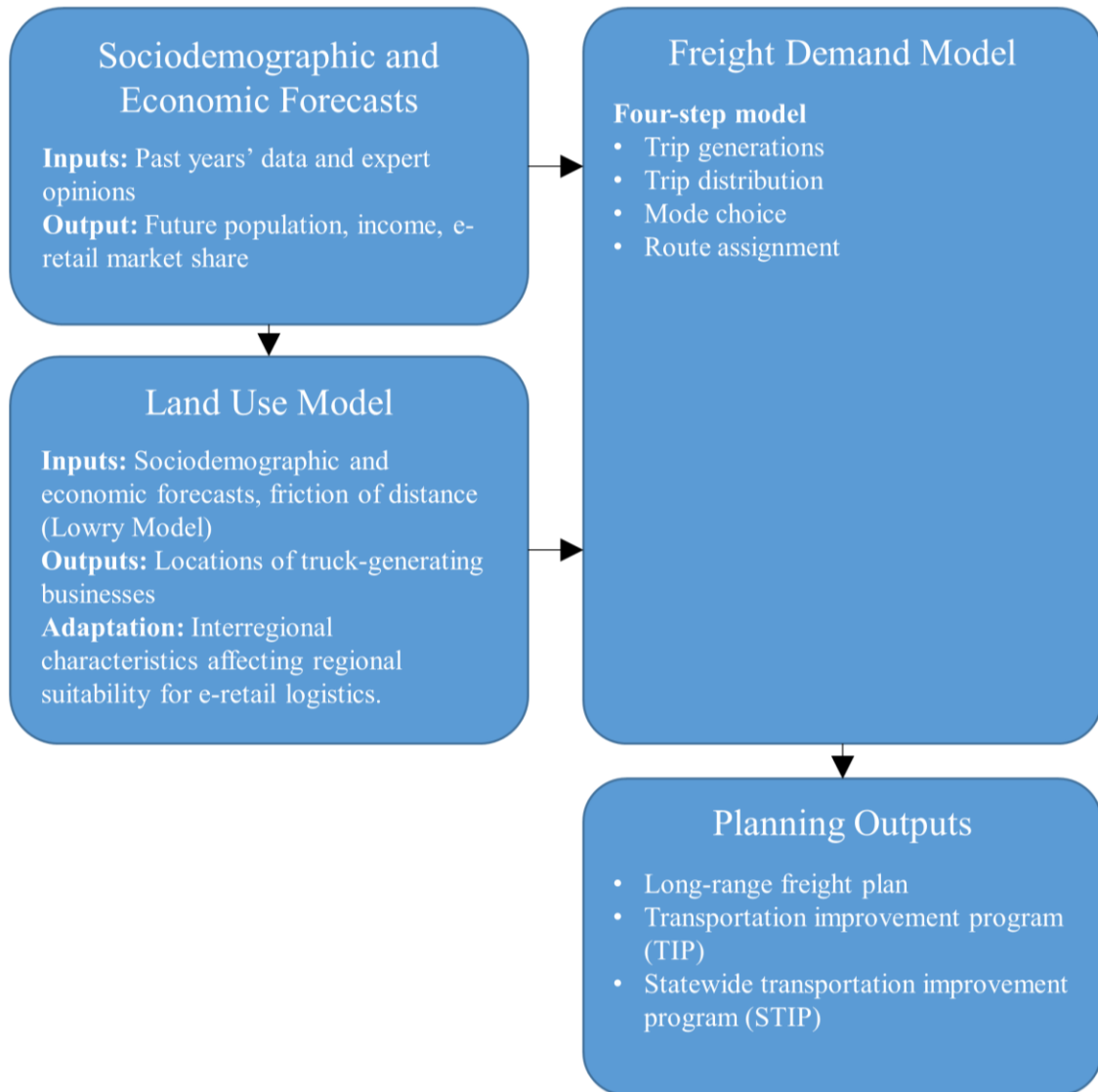
**Note: Items in red refer to planning impacts.**

The following paragraphs summarize archetypal planning responses to e-retail for freight planners, airport planners, economic development planners, and land use planners. The models are conceptual and account for the primary methods employed by each specialty. They are intended to reveal likely impacts on planning methods.

Transportation planning begins with sociodemographic and economic forecasts. Past years' data for variables such as population, wealth, and the size and location of economic sectors are gathered. These sociodemographic and economic forecasts feed into land use models, which ultimately describe trip production and attraction. Land uses combine with forecasted population and economic activity as inputs for freight demand

models. The most common model type is a four-step model that generates trips according to outputs from land use models, links trip origins and destinations through a gravity model, assigns a freight mode to each trip, and then selects an optimal route for that trip. Finally, the model serves to evaluate current transportation networks' adequacy to accommodate forecasted demand and assess projects' improvement, ultimately feeding into the federal transportation funding process through a metropolitan transportation improvement program (TIP) and a statewide transportation improvement program (STIP).

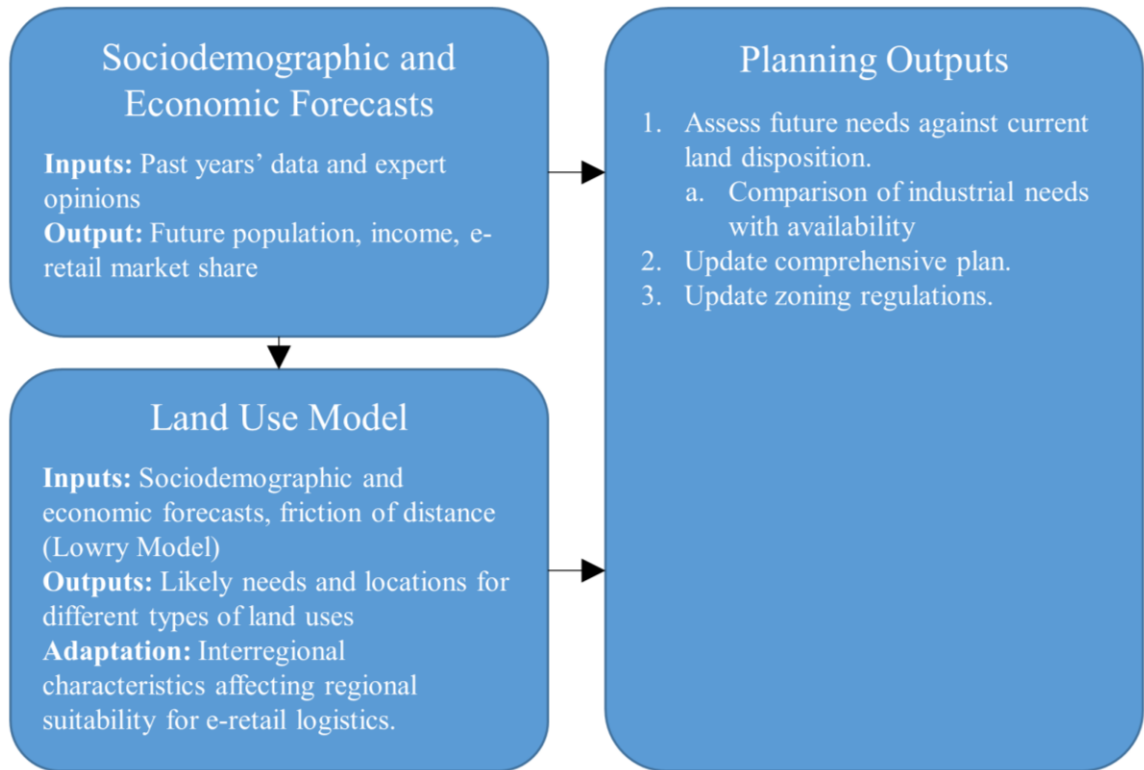
Changing truck movement patterns may affect several of the early steps in the transportation planning process. For instance, if e-fulfillment's location patterns differ from other logistics activity, then the land use model should be sensitive to this change. E-fulfillment's growth may also affect mode split in freight demand models, and it might match trip origins and destinations differently than other logistics activity, both of which would require recalibration of the transportation model. Figure 6 shows the freight demand model and appropriate adaptations to account for e-fulfillment.



**Figure 6. Implications for freight planning.**

Land use models' early steps resemble the freight planning model. Therefore, the adaptations related to e-retail market share in the land use model are identical even though the planning outputs are distinct. Land use planners should compare present demand for industrial land with scenarios forecasting e-fulfillment growth. It may be necessary to update the local comprehensive plan and recommend immediate or future updates to zoned

land. Figure 7 displays adaptation to land use planning's models to account for e-fulfillment.

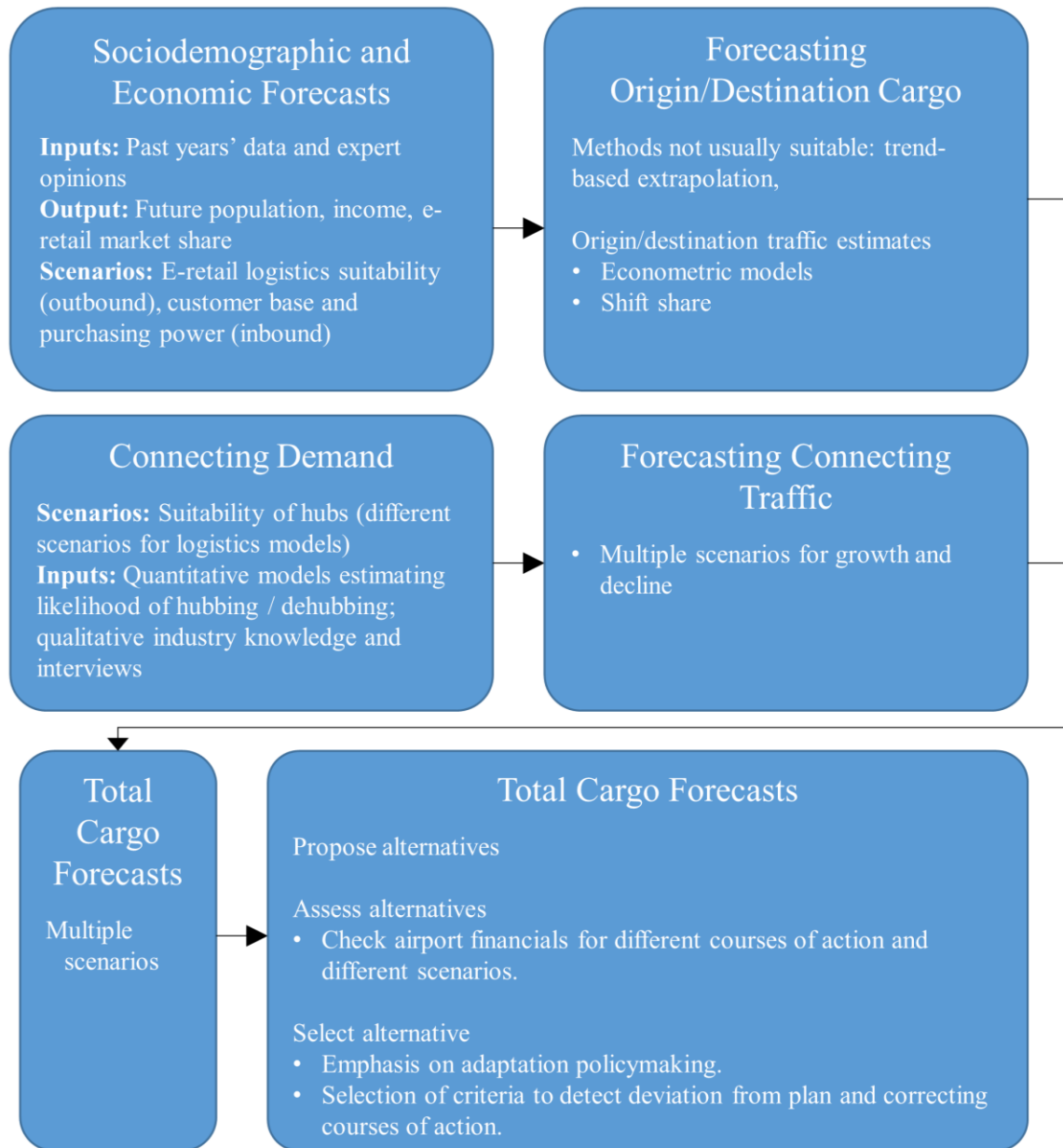


**Figure 7. Land use model.**

Airport planning likewise begins with sociodemographic and economic forecasts. Airport-level cargo activity forecasts follow. These forecasts produce estimates of origin-destination cargo demand. Connecting cargo is often forecast separately because it depends on carrier network decisions. Researchers such as Suh (2017) estimate airports' suitability for a passenger hub, and a similar process can be followed to estimate airports' cargo hub suitability. Forecasted connecting cargo is summed with origin-destination forecasts. As a function of these forecasts, the remainder of the airport planning process occurs according

to the rational planning model: propose, evaluate, and select alternatives based on their ability to economically accommodate air cargo demand.

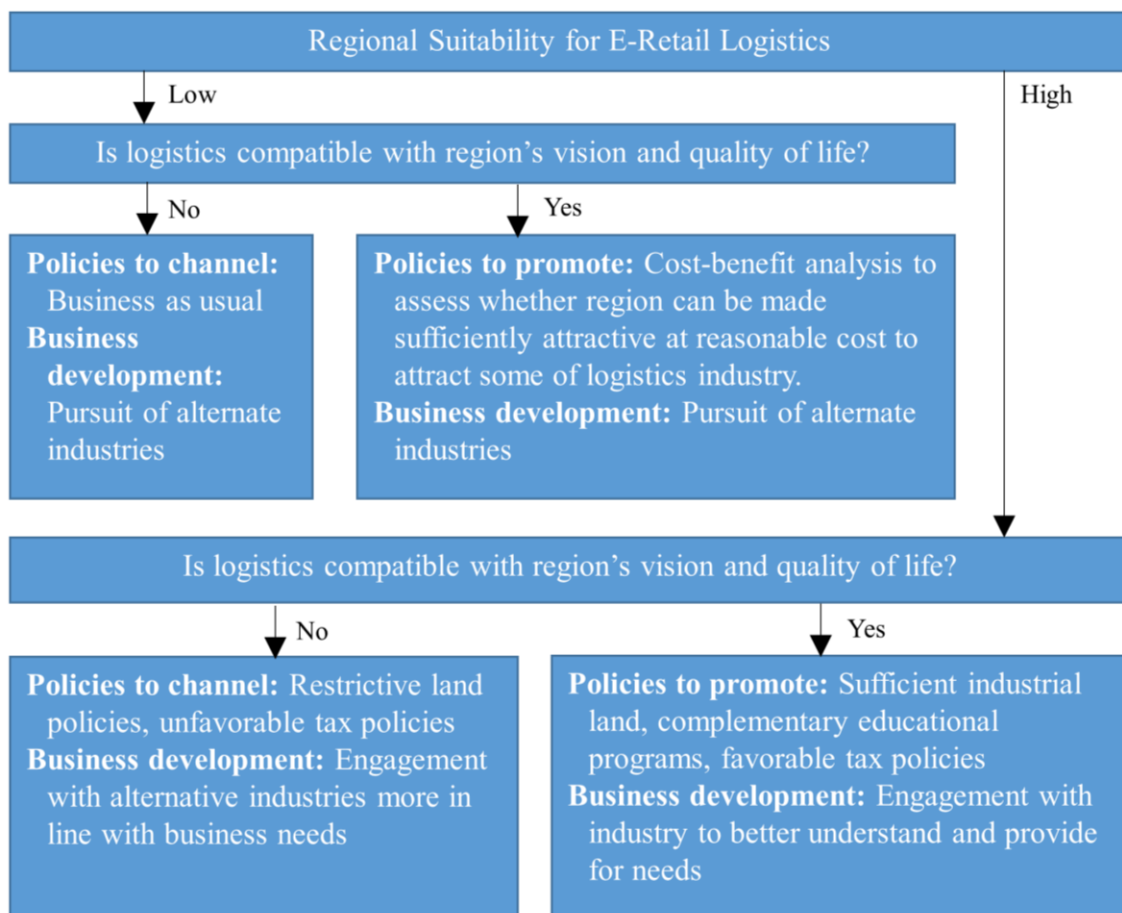
E-fulfillment's growth primarily affects the earliest stages of the airport planning process. Airports in regions that are especially suitable for e-fulfillment may see growth in originating cargo demand. The same is true for destination cargo demand near large consumer markets. Connecting traffic (which neither enters nor leaves the air system at that particular airport) depends most on the growth of e-retail cargo nationwide since cargo networks are likely to remain fixed. Airport planners should pay attention to the first two steps of the airport planning model to account for e-fulfillment. Figure 8 depicts changes to the airport planning model due to e-retail.



**Figure 8. Implications for airport planning.**

Economic development planners face a different task from transportation and land use planners, depicted as a flow chart in Figure 9. For economic development planners, there are two major questions. First, what is the region's suitability for e-fulfillment? Second, does the region's population desire to accommodate new e-fulfillment activity?

The answer to the second question derives from the relative scale and distribution of the benefits of e-fulfillment, such as jobs and tax revenues, and its costs, such truck-related nuisances and infrastructure investment. Based on the regional population's answer to both questions, economic development planners promote, demote, or channel e-fulfillment activity with a set of land use policies, educational programs, transportation investments, and business associations.

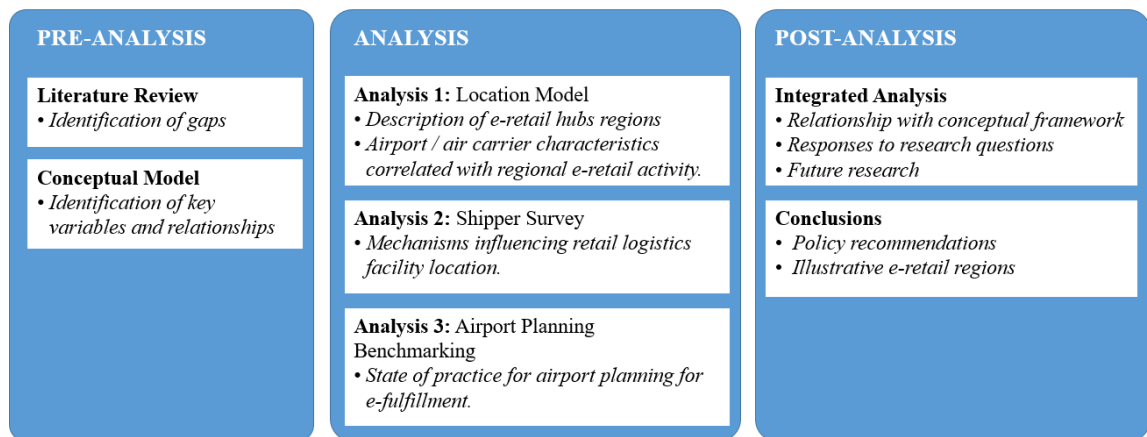


**Figure 9. Implications for economic development planning.**

## CHAPTER 4. METHODOLOGY

### 4.1 Introduction

The dissertation's analysis is conducted in three analytical sections, as shown in Figure 10 and described subsequently. Analysis 1 ("Location Model") associates airport, air cargo, and regional traits with e-fulfillment activity via spatial analysis and linear regression. Analysis 2 ("Shipper Survey") probes the relationships among retail logistics, airports, and air carriers from shippers' perspective. It tests causal explanations for the location model's associations by gathering location preferences and operational highlights directly from retail shippers. Analysis 3 ("Airport Planning Benchmarking") establishes a state of practice in airport staffs' perceptions of and preparations for e-retail through document reviews and staff interviews. The relationships described in Analyses 1 and 2 influence the airport planning categories analyzed in Analysis 3.



**Figure 10. Research methodology.**



## 4.2 Analysis 1 – Location Model

The location model measures how regional traits associated with logistics differ between the sales channels, as described in research question 1 (Q<sub>1</sub>). The alternate hypothesis (H<sub>1</sub>) proposes that e-fulfillment activity is more closely associated with airport proximity and high air connectivity than is B&M retail logistics. FCs' greater reliance on air transport compared with DCs should reflect in greater clustering around airports controlling for other factors. The first research question and associated hypotheses are listed below.

**Q<sub>1</sub>** What airport and air cargo carrier traits are associated with FCs, and are these different from DCs?

**H<sub>0</sub>:** Airports with greater air cargo connectivity are associated with greater FC access compared with DC access.

**H<sub>1.1</sub>:** Airports with greater air cargo connectivity are associated with greater FC access compared with DC access.

The location model's steps are described in the following subsections.

### 4.2.1 *Select Airports and Airport Regions*

The dataset's unit of analysis is the airport, and all airports with at least moderate commercial cargo activity are included. The final dataset includes the 127 airports in the contiguous United States, each of which have over 3 million pounds annual transported freight weight according to the T-100 database (BTS 2015).

#### 4.2.2 *Select Retailers*

One of the greatest challenges in analyzing e-fulfillment activity has been the lack of flow or establishment data for e-fulfillment. The dissertation contributes an original database of DC and FC locations for major retailers in both sales channels. A private dataset called ReferenceUSA serves as the primary source of facility locations. ReferenceUSA claims data on 45 million U.S. businesses (ReferenceUSA 2016b), which it verifies annually (ReferenceUSA 2016a). While assembling the dataset, it was noted that some facilities designated as warehouse serve other functions, and that some known retail warehouses are omitted from the dataset. Therefore, each facility identified by ReferenceUSA is verified with aerial imagery to confirm characteristics typical of warehouses (e.g., large, standalone building; large truck and trailer parking lots; and multiple truck bays on one or more sides of the buildings) as illustrated in Figure 11. Google Map's street view is used to confirm the retailer served by the warehouse. Gaps in ReferenceUSA's data are supplemented with local business news sites (e.g., *Atlanta Business Chronicle*), industry publications (e.g., *Site Selection Magazine*), Google Maps, and corporate websites (e.g., CVSSuppliers.com).



**Figure 11. Typical characteristics of modern DCs.**

**Source: Modified from aerial imagery from Google Maps (retrieved August 2016).**

All retailers from the Top 500 (2016) database with over 80% of sales volume attributable to a single sales channel are included in the sample of retailers. An initial set of warehouses for each retailer is identified from ReferenceUSA. Warehouses serving retailers generating over 80% of their sales from B&M retail are designated as DCs, and warehousing serving retailers generating over 80% of their sales from e-retail are designated as FCs. It is possible to attribute warehouses at the facility level for several retailers. Online searches for facility function are conducted for each retailer, in some cases resulting in a list with facility-level attribution of function. For instance, all Amazon, Walmart, and Target facilities are checked against the facility database compiled by MWPVL Supply Chain Consultants (MWPVL 2017). Logistics facilities that do not hold inventory, such as sortation centers, are excluded.

The final database of warehouses represents 31 B&M retailers, of which the largest by facility area are Walmart, Target, Lowe's and JC Penney. These 31 B&M retailers

operate 257 DCs totaling nearly 19 million square meters. The sample also represents 29 e-retailers, of which the largest by facility area are Amazon, Walmart eCommerce, and Target. These 29 e-retailers operate 168 FCs representing almost 12 million square meters of capacity.

#### *4.2.3 Gather Data*

The remaining data for the regression model are assembled from national government and private datasets identified in Table 4.

#### *4.2.4 Calculate Variables*

Variables are selected based on factors that influence DC and FC location as identified in the literature review. Variables are described in Table 4, and several variables whose calculation description requires additional space are detailed afterwards (i.e., FC access, DC access, and catchment population).

**Table 4. Variables in the location model.**

Topic	Variable	Description	Data Source
Dependent variables	FC access	$FC = \sum_{i \in I} \frac{area_i}{\sqrt{dist_i}}$ <p>where <i>area</i> is the facility floor area in square meters, <i>dist</i> is the Euclidean distance in kilometers to the airport centroid, and <i>i</i> is a given fulfillment center from the whole set <i>I</i>. Additional details provided on page 59.</p>	Calculated
	DC access	$DC = \sum_{j \in J} \frac{area_j}{\sqrt{dist_j}}$ <p>where <i>area</i> is the facility floor area in square meters, <i>dist</i> is the Euclidean distance in kilometers to the airport centroid, and <i>j</i> is a given distribution center from the whole set <i>J</i>. Additional details provided on page 59.</p>	Calculated
Air connectivity	Integrator air hub	Binary variable designating integrator air hubs (AFW BDL CAE CVG DFW EWR GSO IND MEM MIA OAK ONT PHL RFD SDF).	Bowen (2012)
	Domestic passenger destinations	Number of domestic destinations served by passenger aircraft at least once per day on average (excluding aircraft under 100 seats).	Calculated from T-100 (BTS 2015)
	Domestic freighter destinations	Number of domestic destinations served by freighters at least once per day on average.	Calculated from T-100 (BTS 2015)
	International passenger destinations (wide-body)	Number of international destinations served at least once per day on average from a given airport by wide-body passenger aircraft.	Calculated from T-100 (BTS 2015)
	International freighter destinations	Number of international destinations served at least once per week on average from a given airport by cargo freighter aircraft.	Calculated from T-100 (BTS 2015)
Airport operations	Curfew	Binary variable that is 1 if airport has a curfew, 0 otherwise.	Boeing (2017)
Highway access & connectivity	Highway density	Square root of centerline km of Interstate Highways within 25 km of airport.	Calculated from Bureau of Transportation Statistics (2015)

Table 4 (continued).

Topic	Variable	Description	Data Source
	Regional congestion	Travel time index scaled for the percentage of the 25-km radius airport region within each of the 470 statistical areas for which the index is provided.	Texas A&M Transportation Institute (2015)
Seaport access	Containerized Traffic Index (CTI)	$CTI = \sum_{k \in K} \frac{TEU_k}{dist_k^2}$ <p>where <math>TEU</math> is the port's annual TEU volume, <math>dist</math> is the Euclidean distance in kilometers from the port to the airport centroid, and <math>k</math> if a given seaport from the whole set <math>K</math> of river and seaports reported by the U.S. Army Corps of Engineers</p>	Calculated from Navigation Data Center (2015)
Rail access	Rail density	Square root of centerline km of class 1 railroads within 25 km of airport.	Calculated from Bureau of Transportation Statistics (2015)
Customer proximity	Catchment population (regional)	Population accessible by overnight ground, based on mean overnight delivery radius for UPS and FedEx (399 km radius). Additional details provided in section 4.2.4.2.	American Community Survey, U.S. Census Bureau
	Distance to population center (national)	Distance in kilometers to contiguous U.S. (CONUS) population center.	Calculated from ACS 2011-2015, U.S. Census Bureau
Costs	Labor costs	Bottom quintile household annual income approximating low-skill labor costs.	ACS 2011-2015, U.S. Census Bureau
Business environment	State business friendliness	13 ordinal state ratings.	Thumbtack (2015)

#### 4.2.4.1 FC Access and DC Access

Gravity models avoid all-or-nothing attribution inherent in radius-based measures. Instead, each warehouse influences each airport's access score according to a 'weight' that depends on the inverse distance between them. Several powers are tested for the inverse distance (e.g., square root, squared, and non-transformed). When gravity degrades very quickly, scores are distorted such that otherwise insignificant airports with one facility very near the airport receive an unrealistically high score. Gravity model formulations using the square root of distance do not exaggerate the importance of facilities very near the airport, so the model formulation using the square root of distance is selected.

Both sales channels have a single retailer that controls an outsized portion of the market. Amazon has nearly five times the revenue of its nearest e-retail competitor (Wahba 2015), and it operates many more FCs. Due to its size, Amazon may follow a different logistics paradigm than its smaller competitors. Similarly, Walmart constitutes 15% of the total domestic revenue of the largest 100 American retailers (including e-retailers), and Walmart's domestic revenue is roughly four times its nearest non-grocery competitor (National Retail Federation 2016). Walmart's scale may permit it to pursue logistics strategies that are not representative of B&M retailers overall. Therefore, FC access is calculated once with the entire sample of FCs, and a second time excluding Amazon FCs. Similarly, DC access is also calculated with the entire sample DCs, and a second time excluding Walmart DCs. If the location models' results differ when the dominant firms are excluded, it signifies a different pattern in facility location between the dominant retailer and the rest of the industry.

#### 4.2.4.2 Catchment population

The catchment area includes the population accessible via overnight ground transport. E-retailers prefer ground transport's lower cost to air transport's higher cost. Overnight ground transport distance is calculated by averaging the overnight ground delivery radius of UPS and FedEx. ZIP codes for a randomly selected sample of 26 airports out of the 127 airports are input into the web-based tools for FedEx<sup>1</sup> and UPS<sup>2</sup>. The distance from the ZIP code to the edge of the delivery area is measured for the four cardinal directions (North, East, South, West) for each airport. These distances are averaged to produce a single radius that approximates overnight ground delivery area around the country by integrators. The average overnight delivery radius is 399 km, with a standard deviation of 120 km. This distance is overlaid with the population around each airport to produce estimates of the number of people accessible by overnight ground transport from that region.

#### 4.2.5 *Conduct Regressions*

The location model uses an OLS linear regression to examine how airport connectivity, airport operations, and regional traits correlate with an airport's access to FCs and DCs. Four model variants are run. Model 1A has DC access as the dependent variable, while Model 1B has DC access (excluding Walmart DCs) as the dependent variable. Model 2A treats FC access as the dependent variable, while Model 2B treats FC access (excluding Amazon FCs) as the dependent variable.

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<sup>1</sup> <http://www.fedex.com/grd/maps/ShowMapEntry.do>

<sup>2</sup> [https://www.ups.com/maps?loc=en\\_US](https://www.ups.com/maps?loc=en_US)



The models' final forms were determined iteratively. The first model formulations included all independent variables. Independent variables that added little explanatory power or interfere with statistical assumptions were eliminated. Several types of airport variables were evaluated. The 'domestic passenger destinations' variable was excluded because bellyhold cargo transports relatively little domestic e-retail cargo. Several of the other air connectivity variables were correlated with integrator air hub locations. Therefore, integrator air hubs and international passenger destinations (wide-body) were retained. The variables included in each model variant are specified in Table 5.

**Table 5. Location model specifications.**

Category	Variable	DC	DC (No Walmart)	FC	FC (no Amazon)	Comments
Model name	na	1A	1B	2A	2B	
<b>Dependent variables</b>	All DCs	X				
	DCs excluding Walmart		X			
	All FCs			X		
	FCs excluding Amazon				X	
<b>Air connectivity</b>	Integrator air hub	X	X	X	X	
	Domestic passenger destinations					Omitted because carries relatively little e-fulfillment
	Domestic freighter destinations					Omitted because moderately correlated with hub
	International passenger destinations (wide-body)	X	X	X	X	
	International freighter destinations					Omitted because moderately correlated with hub
<b>Airport operations</b>	Curfew					Omitted because present at few airports
<b>Highway access and connectivity</b>	Highway density	X	X	X	X	
	Regional congestion					Omitted because highly correlated with highway density
<b>Rail access</b>	Rail density	X	X	X	X	
<b>Seaport access</b>	Containerized traffic index (CTI)	X	X	X	X	
<b>Customer proximity</b>	Catchment population	X	X	X	X	
	Distance to population center	X	X	X	X	
<b>Business environment</b>	State business friendliness	X	X	X	X	
<b>Costs</b>	Labor costs	X	X	X	X	

Several transformations to the model are executed to meet regression assumptions. Each is described below.

**Natural log transformation of most independent variables:** Many of the dependent variables are positively skewed, which results in a non-linear relationship with the dependent variable. The residuals of models with unmodified dependent variables are examined to identify variables deviating from a linear relationship. When a deviation is found, the natural log of the variable is taken. '0.0001' is substituted for zero in natural log calculations.

**Box-Cox transform of the dependent variable:** The Box-Cox calculation examines the relationships among the variables and recommends a power transform for the dependent variable to improve residuals' normality. The Box-Cox transform is implemented because the location model's unmodified relationships violate the assumption of normally distributed errors. The Box-Cox calculation recommends that the dependent variable be transformed by the power of -0.788 for Model 1A and -1.192 for Model 1B. The power transformations recommended by the Cox-Box calculation are -1.556 for Model 2A and -0.990 for Model 2B. Negative transforms invert high and low values in the dependent variables, which means that model coefficients' signs are reversed. For instance, a negative relationship in Models 1A and 1B signifies that the variable is associated with an *increase* in DC access, while a positive relationship denotes an association with a *decrease* in DC access.

**Remove outlying variables:** One or several airports appear as outliers in q-q plots and variable-specific plots. The outliers are normally airports that host integrator air hubs

and are near the center of exceptionally large logistics clusters. Three airports are removed from the dataset for Model 1A (Hartsfield-Jackson Atlanta International Airport – ATL, Ontario International Airport – ONT, and John Glenn Columbus International Airport – CMH), while no airports are removed for Model 1B. Model 2A did not require any outliers to be removed, while Model 2B saw the removal of two outliers (Ontario International Airport – ONT, and Salt Lake City International Airport – SLC). Removing the outlying airports often eliminated the statistical significance of airport-related variables, which reveals an overdependence of early model results on outliers.

#### *4.2.6 Assess Hypotheses*

The research questions are assessed according to the direction and significance of variables' coefficients, namely air connectivity, airport operations, and catchment population. If they are statistically significant, with coefficients in the hypothesized direction, then the null hypothesis is rejected.

### **4.3 Analysis 2 – Shipper Survey**

The shipper survey is intended to examine associations detected in the logistics model and measure their relative strength by documenting differences in operations and regional needs between FCs and DCs. It tests multiple airport and regional traits that may influence warehouses' operations. Analysis 2's research question (Q<sub>2</sub>) corresponds with three alternate hypotheses, as reported below.

**Q2** What dynamics might explain differences in e-fulfillment and B&M retail logistics locations?

**H<sub>0</sub>:** FC and DC managers assign identical importance to multiple regional, airport, air system, and ground transportation traits.

**H<sub>2.1</sub>:** FC managers rate airports and airport traits as more important than DC managers.

**H<sub>2.2</sub>:** FCs use air cargo for outbound transportation more frequently than DCs.

**H<sub>2.3</sub>:** FCs use integrators and USPS for outbound transportation more frequently networks than DCs.

#### *4.3.1 Shipper Survey*

The survey frame is all warehouses whose addresses are collected for the location model. The surveys were mailed with prepaid and addressed return envelopes to the facility manager's attention during the summer of 2017. The survey is conducted in two rounds: an initial mailing and a reminder. A reminder is identical to the initial mailing except for slight differences in the cover letter. The reminder is mailed to non-respondents one month after the initial mailing.

A pilot survey was conducted with a randomly selected 10% of the sample. A \$2 bill was enclosed in the pilot reminder to increase response rate. Nonetheless, the incentive did not function, and several respondents returned the incentive without completing the survey. Therefore, the incentive was discontinued.

The survey, which is available in “Appendix A. Shipper Survey” asks facility managers to identify regional factors that are important to facility operations, the air system’s role in their operations, and their use of outbound transportation modes and carriers. The survey has four sections. The first ensures that the facility is engaged in retail and gauges the percentage of shipments serving each sales channel. The second section asks the respondent to rate the importance of regional traits to their operations. The third section inquires about outbound shipping modes and carriers. The final section elicits contact information and additional comments.

Responses are analyzed using parametric and non-parametric statistics to compare central tendency among respondents from each sales channel. Statistical tests reveal whether the responses differ enough between sales channels to conclude that the underlying populations are different. Unlike parametric tests, nonparametric tests “do not rely on assumptions about the shape or form of the probability distribution from which the data were drawn” (Hoskin n.d.).

Parametric tests require the data to meet four conditions. The first is independence of samples, which requires that the units being evaluated not be paired with others in a way that would cause their results to theoretically correlate. The survey data meet this assumption since units are unpaired. The second assumption is that the distribution of means be normally distributed. Parametric tests of means are very robust for non-normality, much more so than for regression-based statistics (Norman 2010). The survey data respect the assumption of normality sufficiently to permit parametric tests of means. The third requirement for using parametric tests is that data involve interval numbers. Likert scales such as those used in this survey produce ordinal data as individual responses.

However, parametric methods of central tendency can still be used with Likert data in some cases because the tests are robust to non-normality. Moreover, previous studies have demonstrated robustness to non-normality since “an ordinal distribution amounts to some kind of nonlinear relation between the number and the latent variables” (Norman 2010). The fourth assumption is homoscedasticity, meaning equal variance. The Brown-Forsythe Test assesses the data for homoscedasticity instead of the more common Levene’s test because Brown-Forsythe judges the median, which is most appropriate for data that are technically ordinal (Schlotzhauer 2007). Moreover, the Brown-Forsythe Test better addresses non-normally distributed data (Statistica 2017). Eleven of the 23 questions have unequal variance according to the Brown-Forsythe Test (results shown in Table 6). Therefore, the assumption of homoscedasticity is met in roughly half of the cases.

**Table 6. Results of Brown-Forsythe Test.**

Question	Statistic	Sig.
Q3 <sup>‡</sup>	119.05	0.00
Q4 <sup>‡</sup>	21.40	0.00
Q5a <sup>†</sup>	7.12	0.02
Q5b	0.03	0.87
Q5c	0.03	0.87
Q5d	0.35	0.57
Q5e <sup>‡</sup>	12.69	0.00
Q5f <sup>†</sup>	5.52	0.04
Q5g	2.05	0.17
Q5h	0.00	1.00
Q5i	0.55	0.47
Q5j	0.67	0.43
Q5k*	3.22	0.09
Q7a <sup>‡</sup>	14.36	0.00
Q7b	2.03	0.18
Q7c <sup>‡</sup>	15.71	0.00
Q8a <sup>‡</sup>	24.62	0.00
Q8b	na	na
Q8c	0.14	0.72
Q8d	1.53	0.23
Q9a	1.45	0.25
Q9b	na	na
Q9c <sup>‡</sup>	31.60	0.00
Q9d	1.28	0.28
Q10	na	na
Q11	1.64	0.24
Q12 <sup>†</sup>	5.40	0.03

<sup>‡</sup> p < 0.01, <sup>†</sup> p < 0.05, \*p < 0.10

na: not available



Even though the much of the data meets the assumptions of parametric tests, non-parametric tests are also run to confirm results and control for deviations from parametric assumptions. Non-parametric tests have fewer assumptions about the underlying distribution of the data than parametric tests because they estimate distribution parameters directly from the data. Non-parametric tests necessarily produce more conservative results than parametric tests (Sullivan n.d.). Two non-parametric tests are used. The Mann Whitney U Test assesses whether two samples are from the same population based on their distributions. The Mann Whitney U Test can handle non-normally distributed data and small sample sizes (Sullivan n.d.; Kvam, Vidakovic, and Kim 2007). The second test is the Median Test, which is appropriate when neither equal variance nor normality are present.

Table 7 summarizes the assumptions required for non-parametric tests. Both non-parametric tests require that observations be independent, which the survey data meet. The Mann Whitney U Test requires ordinal data, which is also achieved. The independent variable that groups the data (i.e., sales channel) is dichotomous, as required for the Mann Whitney U Test. Both tests assess whether the distributions are the same. If they are to be construed as assessments of central tendency, then the data in both samples have the same shape. The shapes cannot be reliably compared because of the small sample size and the small number of categories, which make the data bounds very narrow. Test results should be construed conservatively.

**Table 7. Assumptions of non-parametric tests.**

<b>Assumption</b>	<b>Applicable Tests</b>	<b>Assessment</b>
Independence of observations	Mann Whitney U Test Median Test (Taylor 2016)	Met
Ordinal data	Mann Whitney U Test	Met
One dichotomous independent variable	Mann Whitney U Test	Met
Same shape of distribution	Mann Whitney U Test Median Test	Cannot be reliably determined because sample size too small and too few categories

#### *4.3.2 Logistics Interviews*

Interviews with logistics experts supplement the shipper survey. While surveys are adept at identifying trends and their prevalence among different types of respondents, they are less capable of probing emerging issues and documenting nuance. Interviews compensate for the surveys' low response rate. Interviews also expand the survey sample beyond the relatively few retailers that responded to the survey. For instance, economic development planners may interact with many retailers and be familiar with the trends motivating a large set of retailers.

Interviews were conducted with 11 professionals who work in e-fulfillment or collaborate with e-retailers. Interviewees represent e-retailers, cargo consultants, integrators, airlines, and chambers of commerce. Interviewees were recruited through cold-calls and through personal, research, and business networks. The interviews are analyzed using a theory-based codebook. Table 8 describes the interviewees according to three categories of affiliation.

**Table 8. Interview list.**

<b>Position</b>	<b>Mode</b>
<b>RETAIL</b>	
Retail logistics manager	Phone interview
Former logistics site selection consultant	In-person interview
Chamber of commerce employee, logistics	In-person interview
Chamber of commerce employee, logistics	Phone interview
Manager in state-level logistics center	Phone interview
<b>CARRIERS</b>	
Integrator management-level employee	In-person interview
Air cargo consultant	Phone interview
Air cargo consultant	Written correspondence
Passenger airline cargo manager	In-person interview
Former president of regional air cargo association	Phone interview
<b>REAL ESTATE</b>	
Industrial real estate researcher	Phone interview

#### **4.4 Analysis 3. Airport Planning Benchmarking**

Analysis 3 examines the extent to which airport staff and leadership planning for changes in air cargo demand associated with e-fulfillment. Compared with Analyses 1 and 2 that assume the shipper's perspective, Analysis 3 adopts the airport staff's perspective. The research question (Q<sub>3</sub>) asks how airports with e-retail cargo activity perceive and plan for the cargo type. No alternate hypotheses are provided because the question is exploratory.

**Q<sub>3</sub>** How are airport planners preparing for e-retail cargo?

**H<sub>0</sub>:** Airport planners are not planning for e-fulfillment.

The third research question is decomposed into sub-questions, lettered ‘a’ through ‘e.’ Each sub-question corresponds with a theme pursued in the analysis.

**Q<sub>3a</sub> (‘e-fulfillment influence’):** Is e-fulfillment perceived as an influence on air cargo demand?

**Q<sub>3b</sub> (‘forecasting’):** Are the technical forecasting steps likely to account for air cargo activity or patterns related to e-fulfillment?

**Q<sub>3c</sub> (‘freight community involvement’):** Does freight community involvement implicitly or explicitly involve e-retailers?

**Q<sub>3d</sub> (‘investments and policies’):** Do the plans analyze investments or policies to respond to e-retail air cargo needs?

**Q<sub>3e</sub> (‘land development’):** Does airport planning consider on- or off-airport land development related to e-fulfillment?

#### *4.4.1 Selection of Airports for Document Reviews*

The airports for review are selected with a three-stage process that progressively narrowed the initial set of 127 airports down to 49 candidate airports, and 10 airports for document reviews, as depicted in Figure 12. The airports selected for document review have traits that make e-retail likely to be prominent enough to warrant planning attention.

Step <i>Number of airports</i>	Conditions
<b>All Airports</b> 127 airports	Airports with more than 3 million pounds annually emplaned cargo
<b>Candidate Airports</b> 49 airports	<ol style="list-style-type: none"> <li>1. Regional e-retail activity</li> <li>2. Cargo enplanement</li> <li>3. Integrator hub</li> <li>4. Known e-retail strategy</li> </ol>
<b>Document Review</b> 10 airports	<ol style="list-style-type: none"> <li>5. Importance in e-fulfillment networks</li> <li>6. Master plan availability</li> <li>7. Plan or study timeliness</li> <li>8. Diverse set of airports</li> </ol>

**Figure 12. Document review selection process.**

Candidate airports for document review are selected based on four criteria defined below that raise the likelihood of the airport experiencing sufficient e-retail cargo activity to justify planning attention. Airports are retained for further consideration when they meet two or more of the first three criteria. The fourth criterion can qualify an airport for further consideration independently of the first three.

1. **Regional e-fulfillment activity:** Airport regions with more e-fulfillment activity identified in the location model are likely to generate e-retail air cargo shipments. The 30 airport regions with the greatest e-fulfillment activity (as defined by summed facility area within 50 km) are retained.
2. **Cargo enplanement:** Airports with substantial cargo activity are likely to plan for cargo. Airport cargo enplanement is measured by weight, and the 30 airports with the greatest enplanement in 2015 are retained.
3. **Integrator air hubs:** All airports that host a hub for UPS, FedEx, or DHL are retained as candidates.

4. **Known e-fulfillment strategy:** Any airports not otherwise included in the dataset that have been previously identified as pursuing a strategy to attract e-fulfillment are included. The only airport added due to this criterion is Piedmont Triad International Airport (GSO).

The resulting 25 candidate airports are evaluated with four additional criteria to determine which would be useful for the document review. A full table evaluating the candidate airports is available in Appendix B.      Selection of Airports for Document Review.

5. **Importance in e-fulfillment networks:** Airports that are especially important in e-fulfillment networks are reviewed. For instance, Amazon recently selected Cincinnati/Northern Kentucky International Airport (CVG) as the site of its long-term air cargo hub. Similarly, John F. Kennedy International Airport (JFK) is a large international gateway that accommodates many international e-retail shipments.
6. **Master plan or cargo study availability:** Only some airports make master plans or cargo studies available to the public. Airports for which a master plan or cargo study could not be obtained are removed from consideration.
7. **Plan or study timeliness:** E-fulfillment has become a force in airport planning in the past decade or less. Therefore, only plans completed after 2008 are retained, and airports with the most recent plans are prioritized.

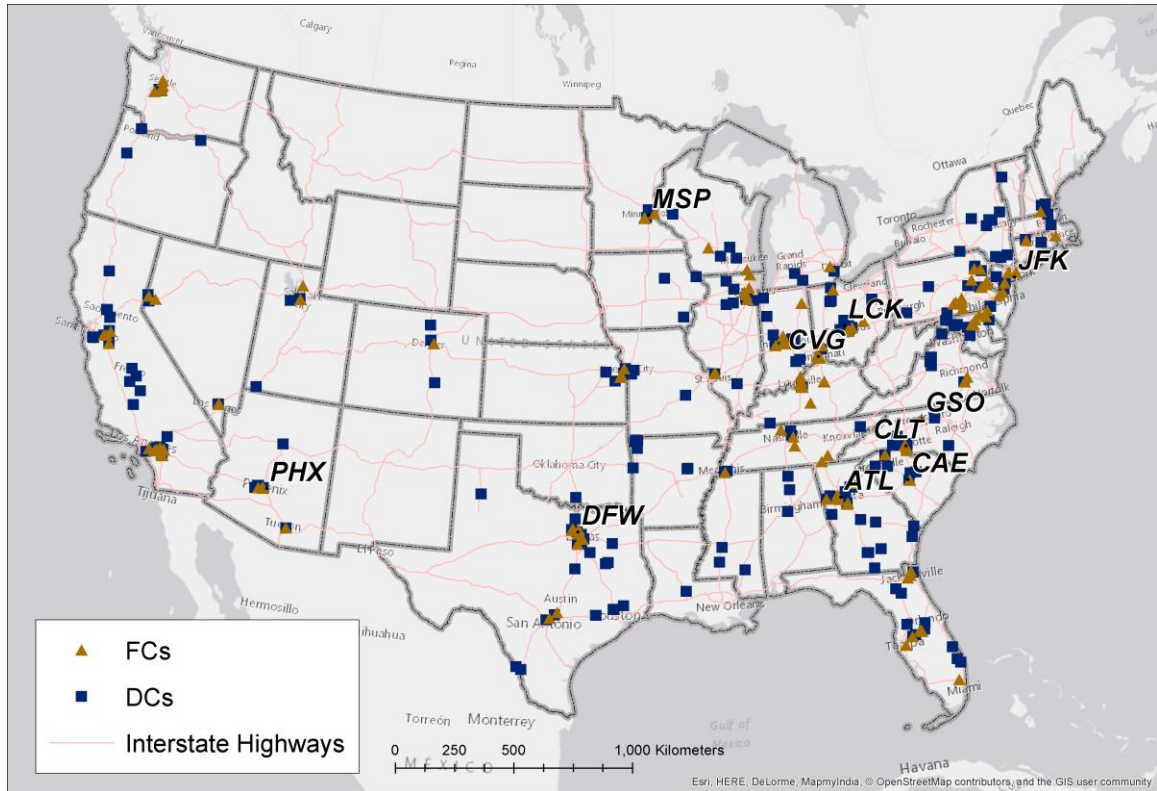
8. **Diverse set of airports:** The airports for document review are selected to produce a diverse set of airports by geographic region, hub status, international gateway status, cargo activity, passenger activity, and ownership.

The airports designated in Table 9 are selected for document review. Each airport is hereafter identified by its three-letter International Air Transport Association (IATA) code.

**Table 9. Airports selected for document review.**

<b>IATA code</b>	<b>Name</b>	<b>City and state</b>
ATL	Hartsfield–Jackson Atlanta International Airport	Atlanta, GA
CAE	Columbia Metropolitan Airport	Columbia, SC
CLT	Charlotte Douglas International Airport	Charlotte, NC
CVG	Cincinnati/Northern Kentucky International Airport	Cincinnati, OH
DFW	Dallas/Fort Worth International Airport	Dallas, TX
GSO	Piedmont Triad International Airport	Greensboro, NC
JFK	John F. Kennedy International Airport	New York, NY
LCK	Rickenbacker International Airport	Columbus, OH
MSP	Minneapolis-St. Paul International Airport	Minneapolis, MN
PHX	Phoenix Sky Harbor International Airport	Phoenix, AZ

Figure 13 reveals that the airports for document review skew towards the eastern half of the country, like e-fulfillment generally. It was attempted to add airports in the western U.S. However, many candidate airports (e.g., Ontario International Airport - ONT, Seattle-Tacoma International Airport - SEA, Oakland International Airport – OAK, Los Angeles International Airport - LAX) do not have recent plans or studies available.



**Figure 13. Airports for document review.**

#### 4.4.2 Selection of Airports for Interviews

Airports hosting Amazon Prime Air flights are selected for interviews because they experience visible air cargo activity related to e-retail. At other airports, e-retail cargo is often invisible because it is categorized as mail or consolidated by freight forwarders. Staff at airports hosting Amazon Prime Air were contacted for interviews. Staff at seven airports located in different parts of the country participated in interviews. In addition, two airport consultants focusing on e-commerce participated via phone or email.

#### 4.4.3 Analytical Categories

The first step in analyzing the airport plans and interviewing airport officials is to select thematic categories that correspond with the five previously identified research sub-



questions (Q<sub>3a</sub> - Q<sub>3e</sub>). The thematic categories are e-fulfillment influence, forecasting, freight community involvement, investments and policies, and land development. Each thematic category is detailed below.

#### 4.4.3.1 E-fulfillment influence (Q<sub>3a</sub>)

The first subsection assesses whether the airport staff perceives e-fulfillment as an influence on airport cargo activity or airport business development. The topic does not imply that e-fulfillment should be a business development goal. The document reviews gauge e-fulfillment's perceived influence by searching for either explicit mention of e-fulfillment or an implicit allusion to e-fulfillment. An allusion might reference forces shaping air cargo, nearby fulfillment centers, or integrators.

#### 4.4.3.2 Forecasting (Q<sub>3b</sub>)

The forecasting subsection examines the forecasting approach. Approaches are sensitive to cargo dynamics, e-fulfillment dynamics, and / or passenger dynamics. Scarce data on e-retail air cargo makes it improbable that any airport quantitatively forecasts e-retail air cargo. Therefore, the forecasting methods are primarily analyzed for adaptability to e-fulfillment, as summarized in Table 10. Forecasting air cargo is extremely difficult, and there are many reasons why an airport might select a given approach. The goal is not to criticize or correct, but rather to describe a state of practice.

**Table 10. Forecasting approaches' potential sensitivity to e-fulfillment.**

<b>Class of Approach</b>	<b>Category of Approach</b>	<b>Possible to Consider E-fulfillment?</b>
Cargo forecasts not performed	Neither passenger nor cargo forecasts	No
	Passenger forecasts only	No
Qualitative	Judgment forecasts	Yes
Quantitative	Time-series trend analysis	No
	Regression analysis	Yes
	Market share analysis	Yes
Mixed	Scenarios based on airline activity	Yes

**Note: Categories adapted from Maynard et al. (2015). Scenario approach derived from CVG 2035 Master Plan (Kenton County Airport Board 2013).**

#### 4.4.3.3 Freight community involvement (Q<sub>3c</sub>)

The freight community involvement subsection is a review of the freight stakeholder involvement in the planning process. Ideally, e-retailers are consulted. Other freight community members that can provide information about e-fulfillment include third-party logistics companies (3PLs), air carriers, integrators, labor unions, developers, real estate brokers, economic development planners, freight planners, and chambers of commerce. The document reviews note freight community involvement in planning.

#### 4.4.3.4 Investments and policies (Q<sub>3d</sub>)

The fourth subsection on investments and policies evaluates the analysis included of the plan of future infrastructure needs. Process rather than outcome is the subsection's focus. The subsection does not examine the specific projects that are recommended because e-retail shipments intermix with general cargo.

#### 4.4.3.5 Land development (Q<sub>3e</sub>)

The fifth subsection on land development is a review of the plan's recommendations for accommodating e-fulfillment on or near airport-property. Airport-centric development models (e.g., Aerotropolis, Airport City) emphasize a close connection between on-airport activity and nearby land development. Airport staff may seek to promote cargo-generating activities around the airport or promote regional development more generally.

## **CHAPTER 5. LOCATION MODEL**

### **5.1 Introduction**

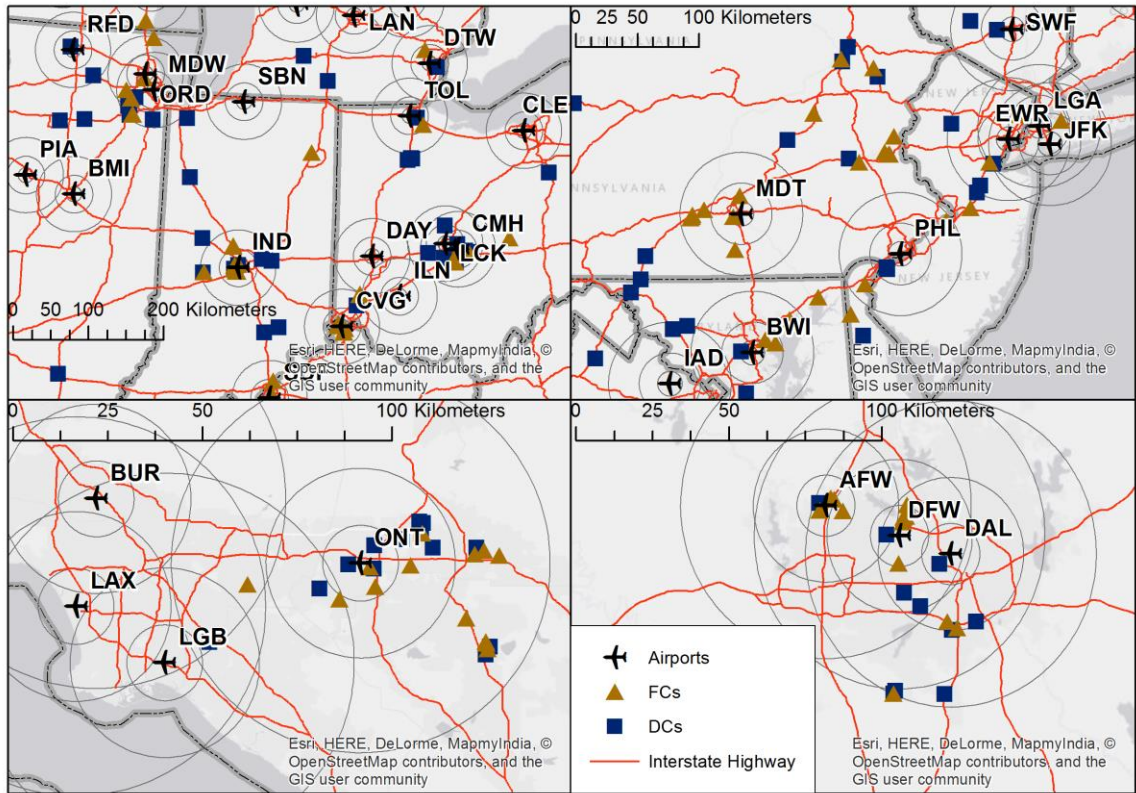
This chapter is an examination of location choice for warehouses of leading e-retailers and B&M retailers. The chapter contains four sections. The first section (“Spatial Analysis”) is a description the locations of the warehouses in the United States and their associations with airports. The second section (“Correlations”) displays correlations among all the variables using Pearson’s correlation coefficient. The third section (“Location Models”) includes an explanation of regression results, and the last section (“Conclusions”) draws lessons.

### **5.2 Spatial Analysis**

The spatial analysis confirms that airport regions host disproportionate e-fulfillment activity. DCs concentrate east of a line connecting Minneapolis, MN to San Antonio, TX, with smaller clusters on the West Coast and in the Mountain states. Many DCs are outside of airport regions, and Walmart demonstrates an especially pronounced pattern of siting DCs outside major metropolitan areas, possibly because of its disproportionately rural customer base. Figure 15 shows DCs’ and FCs’ locations.

The Northeast Corridor between Washington DC and New York City contains many DCs and FCs, especially along the I-95 corridor and in the Lehigh Valley. Many of the facilities cluster outside of major metropolitan regions. Some retailers that use the region’s seaports and airports store inventory in these lower-cost, less congested hinterlands (Morris 2017a; C. Lewis 2016). Four regions with significant retail logistics

activity including the Northeast Corridor (upper right) are displayed in Figure 14 for illustrative purposes.



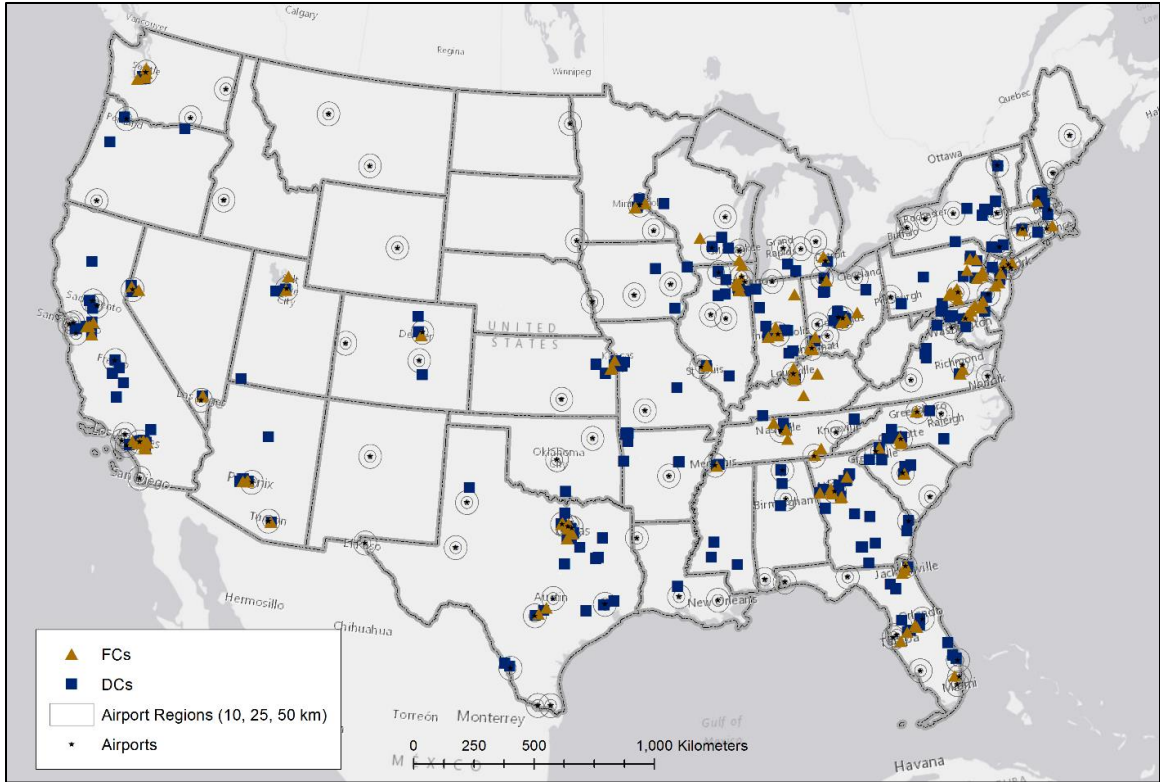
**Figure 14. Details of metro areas.**

**Note: Northeast Corridor, Dallas - Fort Worth, Southern California, and Midwest (clockwise starting upper right).**

Dallas-Ft. Worth, TX is in the lower right of Figure 14. FCs and DCs cluster tightly around Fort Worth Alliance Airport (AFW), which hosts a FedEx air hub (Bowen 2012); Dallas/Ft. Worth International Airport (DFW), which hosts a UPS hub; and suburbs south of the city of Dallas. Moving clockwise, Southern California has long been a major center of imports and distribution, and the Inland Empire is a major retail logistics hub. Ontario International Airport (ONT) also hosts a UPS air hub (Bowen 2012). The Midwest contains

several retail logistics clusters, focused around the greater Chicago region; Indianapolis, IN; Louisville, KY; Cincinnati, OH; and Columbus, OH. Finally, the Northeast exhibits clusters of FCs and DCs in Maryland, New Jersey, and eastern Pennsylvania, which are accessible to customer bases and transportation networks in the region's major metropolitan areas.

Compared with DCs, very few FCs are in small cities or rural areas. FCs congregate more tightly around fewer airports than DCs. 52% of FC floor area is within 25 km of the airports, compared with 32% of DC floor area, and the average FC has greater accessibility to the air cargo network than the average DC. Nationwide, domestically oriented FCs moderately cluster within just a few airport regions, especially in the Midwest, Texas, and Southern California. The patterns remain even when Amazon, the largest e-retailer and a strategic outlier, is excluded. The five airport regions with the greatest FC access all host integrator air hubs (Indianapolis, IN – IND; Fort Worth, TX – AFW; northern Kentucky – CVG; Louisville, KY – SDF; and Dallas, TX - DFW in decreasing order). The increase in FC access over DC access is greatest for these same regions, which signals that they are well positioned to capture more e-fulfillment activity as the sales channel grows.



**Figure 15. Airport regions, FCs, and DCs.**

### 5.3 Correlations

A Pearson correlation coefficient is calculated for each pair of variables described in Chapter 4 (“Methodology”). A coefficient of zero indicates that there is no correlation, a coefficient of 1 indicates perfectly positive correlation, and a coefficient of -1 indicates perfectly negative correlation. The four dependent variables (i.e., DC access, DC access excluding Walmart, FC access, and FC access excluding Amazon) are highly intercorrelated, with coefficients of 0.82 or above, which quantifies the fact that the dynamics that motivate FC and DC locations are frequently shared. Additionally, FC and DC access highly correlate with catchment population and distance to population center (which estimate regional and national population access respectively). Among the transportation variables, FC and DC access most highly correlate with highway density

(coefficients of 0.34 and above) and integrator air hubs (coefficients of -0.21 and below).

Table 11 displays the Pearson correlation coefficients of all variable pairs. Cells are shaded to facilitate interpretation. Dark green denotes a strongly positive correlation, and dark red denotes a strongly negative correlation.



**Table 11. Pearson correlation coefficients among variables in location model.**

	DC access	DC access (no Walmart)	FC access	FC access (no Amazon)	Integrator hub	LN(International passenger destinations)	LN(Highway density)	LN(Containerized traffic index)	Railroad density	LN(Catchment population)	Distance to population center	LN(Labor costs)	Business environment
DC access	1.00	0.96	0.94	0.90	-0.21	0.11	-0.34	-0.03	-0.38	-0.82	0.68	-0.21	0.03
DC access (no Walmart)	0.96	1.00	0.89	0.82	-0.24	0.06	-0.38	-0.16	-0.38	-0.82	0.50	-0.28	0.20
FC access	0.94	0.89	1.00	0.95	-0.26	0.01	-0.39	-0.05	-0.39	-0.79	0.67	-0.23	-0.03
FC access (no Amazon)	0.90	0.82	0.95	1.00	-0.26	0.02	-0.34	-0.03	-0.37	-0.69	0.67	-0.10	-0.13
Integrator air hub	-0.21	-0.24	-0.26	-0.26	1.00	0.06	0.13	0.14	0.07	0.16	-0.04	0.09	-0.14
LN(International passenger destinations)	0.11	0.06	0.01	0.02	0.06	1.00	0.21	0.36	0.02	0.08	0.26	0.18	-0.12
LN(Highway density)	-0.34	-0.38	-0.39	-0.34	0.13	0.21	1.00	0.24	0.37	0.36	-0.13	0.37	-0.18
LN(Containerized traffic index)	-0.03	-0.16	-0.05	-0.03	0.14	0.36	0.24	1.00	-0.07	0.29	0.47	0.12	-0.36
Railroad density	-0.38	-0.38	-0.39	-0.37	0.07	0.02	0.37	-0.07	1.00	0.26	-0.32	0.08	0.06
LN(Catchment population)	-0.82	-0.82	-0.79	-0.69	0.16	0.08	0.36	0.29	0.26	1.00	-0.36	0.30	-0.20
Distance to population center	0.68	0.50	0.67	0.67	-0.04	0.26	-0.13	0.47	-0.32	-0.36	1.00	-0.04	-0.36
LN(Labor costs)	-0.21	-0.28	-0.23	-0.10	0.09	0.18	0.37	0.12	0.08	0.30	-0.04	1.00	-0.31
Business environment	0.03	0.20	-0.03	-0.13	-0.14	-0.12	-0.18	-0.36	0.06	-0.20	-0.36	-0.31	1.00

**Note: Dark green indicates a strong positive correlation, and dark red indicates a strong negative correlation.**

## 5.4 Location Models

The location models predict FC and DC access as a function of regional and airport traits. The models and variables employed are detailed in Chapter 4. An ordinary least squares (OLS) linear regression is used. Regression assumptions need to be strictly respected for model results to be valid. Accordingly, several transformations are applied to the dependent variables (i.e., power transform based on Box-Cox calculation) and most of the independent variables (i.e., natural log). The transformations complicate data interpretation. Notably, the Box-Cox transform of the dependent variable inverts high and low values, thereby reversing the direction of the relationships. To assist in interpretation, the results table contains a column (“Association with...”) that describes the direction of the relationship between the independent variables and the unmodified dependent variable.

### 5.4.1 DC Location Models

The DC models predict DC access as a function of regional and airport traits. Walmart is an outlier among retailers, so two models are run with different versions of DC access. Model 1A includes a DC access variable calculated from the entire DC sample, and Model 1B includes a DC access variable calculated from the sample excluding Walmart. The results from the two models are explained below, and the numeric results are reported in Table 12.

Models 1A and 1B have high explanatory power, describing nearly 90% of the variation in the data according to the reported  $R^2$ s. The results largely align with expectations, although some regional traits are not statistically significant, possibly due to

small sample size. Seven of the nine variables are statistically significant in one or both models.

Integrator air hubs are associated with greater non-Walmart DC accessibility (Model 1B) and have no perceptible effect in Model 1A. The relationship between DC access and integrator air hubs in Model 1B may derive from the overlap between integrators' ground and air networks. Walmart operates its own trucks (Wal-Mart Stores, Inc. 2017), but smaller retailers outsource ground transportation to integrators or 3PLs. Past studies corroborate spatial overlap between integrator air hubs and general logistics activity (Cidell 2010). DC location may associate with integrator air hubs because of co-located surface transportation.

International passenger service is not expected to affect DC locations because so little B&M cargo originating at DCs is transported aboard passenger aircraft. Nonetheless, Models 1A and 1B reveal a negative association between the number of international destinations served by wide-body passenger aircraft and DC access. A plausible explanation is that a third variable, such as land or labor costs, relates to both. Regions with little or no international passenger service typically have lower population density, lower land prices, and potentially lower congestion, all of which are favorably associated with retail logistics.

Trucks transport most retail goods for at least a portion of their movement, and long-distance trucks typically travel on Interstate Highways. Past research has shown highway access to strongly influence warehouse location (Sivitanidou 1996; Cidell 2010; Jakubicek and Woudsma 2011). There is a statistically insignificant relationship between

highway density and DC access. The formulation of these models differs enough in geographic extent from past studies' formulations to attenuate the relationship between highway density and DC access. DC access's calculation surpasses the boundaries of the airport region since it derives from a gravity model. It relates to the airport's centrality in the entire sample of DCs, while highway density only accounts for roads within 25 km of the airport. By contrast, other parts of the surface transportation network do associate with DC access. Seaport access is associated with DC activity, which aligns with past sub-national studies (Awasthi, Chauhan, and Goyal 2011; Notteboom and Rodrigue 2004). Likewise, rail density is associated with greater DC access, which has been hypothesized and sometimes confirmed (Cidell 2010).

DCs' proximity to customers, both at the regional and national levels, is by far the most important factor affecting DC access. Having a larger population in the catchment area (399 km radius) is strongly and positively associated with DC access. DCs generally need to be in a region that allows for inexpensive and fast replenishment of store inventories, which prompts them to locate within a few hundred miles of customer groupings. The same effect extends to national-level population distributions as measured by the variable called 'distance to population center.' The contiguous national population center is calculated in ESRI's ArcMap as being in Missouri, and regions located closer to this point tend to also experience greater DC access. The attraction of the national population center also aligns with the logistics industry's geographic shift towards the Missouri and Ohio River Valleys (Cidell 2010).

Neither Model 1A nor Model 1B display an association between blue-collar labor cost and DC access. There is no association despite DCs' sensitivity to labor costs. Moving

from a region with below average labor costs to a region with above average labor costs can increase a DC's labor costs by roughly 42% and its overall costs by 17% (BizCosts 2010).

Past research has suggested that DCs seek regions with low operating costs and minimal regulation (Jakubicek and Woudsma 2011). Therefore, the models include a state-level measure of the business environment. Both models reveal business environment to be highly significant, but not in the hypothesized direction. In fact, airports in less business-friendly states experience greater DC access on average than airports in more business-friendly states. There are plausible explanations for the negative relationship. Large populations present in some states with low business friendliness may outweigh the importance of the regulatory environment. Additionally, state policy may be less influential than local policy.

Table 12 presents the detailed results for Model 1A predicting DC access of the entire sample and Model 1B predicting DC access of the sample excluding Walmart. Because of the power transform to the dependent variables, the direction of the relationships detected is reversed. Therefore, the direction of the unmodified relationship is indicated in the column titled "Association with DC Access."

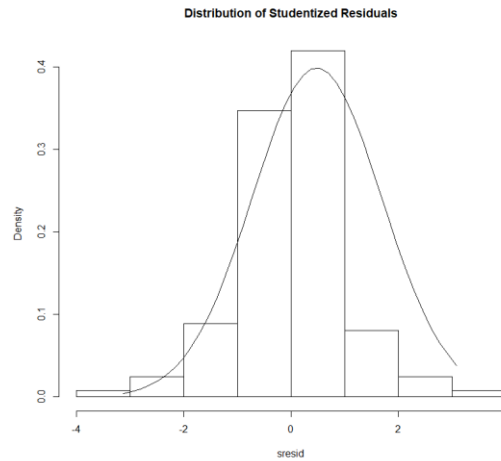
**Table 12. Results of DC location Models 1A and 1B.**

	Model 1A: Transformed DC access (all DCs)					Model 1B: Transformed DC access (all DCs except Walmart)				
	Coef.	Beta	Std. Error	Sig.	Association with DC Access	Coef.	Beta	Std. Error	Sig.	Association with DC Access
(Intercept)	0.01	na	3.3E-03	0.00 ‡	na	2.7E-03	na	8.0E-04	0.00 ‡	na
<b>Integrator air hub (binary)</b>	-1.4E-04	-0.05	9.5E-05	0.15	Not detected	<b>-4.6E-05</b>	<b>-0.09</b>	<b>2.2E-05</b>	<b>0.04 †</b>	<b>Positive</b>
<b>LN(Destinations served by non-stop wide-body passenger aircraft)</b>	<b>1.1E-05</b>	<b>0.08</b>	<b>4.9E-06</b>	<b>0.03 †</b>	<b>Negative</b>	<b>2.2E-06</b>	<b>0.09</b>	<b>1.2E-06</b>	<b>0.06 *</b>	<b>Negative</b>
LN(Highway density)	-1.6E-05	-0.02	3.4E-05	0.63	Not detected	-4.2E-06	-0.03	8.1E-06	0.61	Not detected
<b>LN(Containerized traffic index)</b>	<b>-1.0E-04</b>	<b>-0.10</b>	<b>4.6E-05</b>	<b>0.03 †</b>	<b>Positive</b>	<b>-2.0E-05</b>	<b>-0.11</b>	<b>1.1E-05</b>	<b>0.07 *</b>	<b>Positive</b>
<b>Rail density</b>	-2.9E-07	-0.04	2.5E-07	0.24	Not detected	<b>-1.5E-07</b>	<b>-0.13</b>	<b>5.8E-08</b>	<b>0.01 ‡</b>	<b>Positive</b>
<b>LN(Catchment population)</b>	<b>-6.5E-04</b>	<b>-0.57</b>	<b>4.9E-05</b>	<b>0.00 ‡</b>	<b>Positive</b>	<b>-1.1E-04</b>	<b>-0.59</b>	<b>1.2E-05</b>	<b>0.00 ‡</b>	<b>Positive</b>
<b>Distance to population center</b>	<b>7.4E-07</b>	<b>0.53</b>	<b>6.7E-08</b>	<b>0.00 ‡</b>	<b>Negative</b>	<b>7.8E-08</b>	<b>0.33</b>	<b>1.6E-08</b>	<b>0.00 ‡</b>	<b>Negative</b>
LN(Labor cost)	1.2E-04	0.01	3.2E-04	0.71	Not detected	-2.3E-05	-0.01	7.8E-05	0.77	Not detected
<b>Business environment</b>	<b>1.7E-05</b>	<b>0.08</b>	<b>8.1E-06</b>	<b>0.04 †</b>	<b>Negative</b>	<b>5.7E-06</b>	<b>0.15</b>	<b>1.9E-06</b>	<b>0.00 ‡</b>	<b>Negative</b>

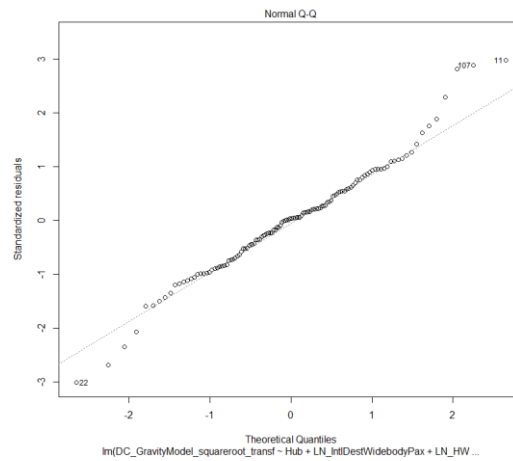
**R<sup>2</sup> for Model 1A: 0.893, n=124; R<sup>2</sup> for Model 1B: 0.893, n = 127**

**‡ p< 0.01, † p< 0.05, \*p< 0.10**

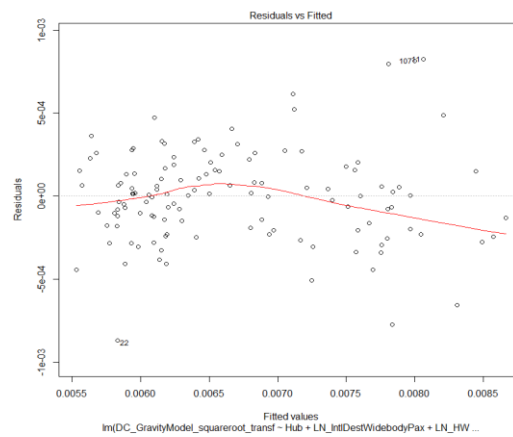
Normality (histogram of residuals)



Normality (q-q plots)

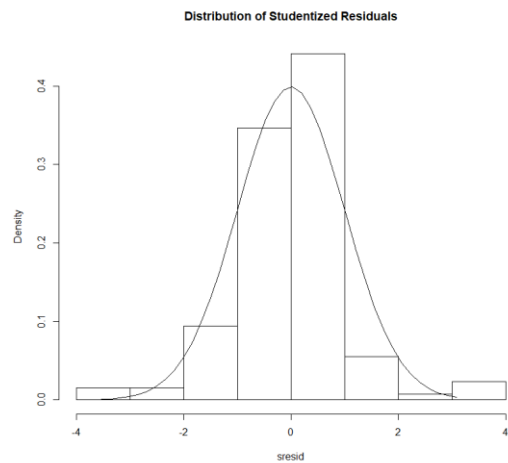


Heteroscedasticity (scatter plot of predicted values versus residuals)

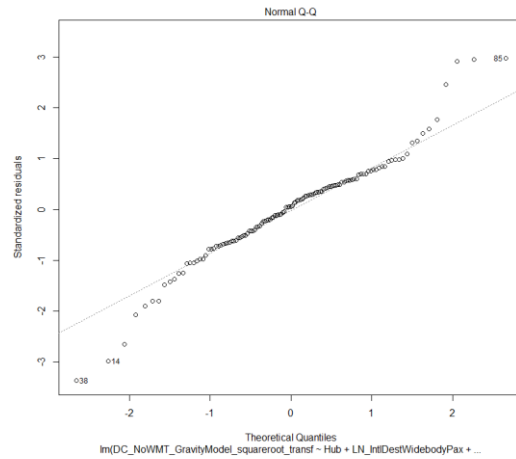


**Figure 16. OLS assumptions for Model 1A.**

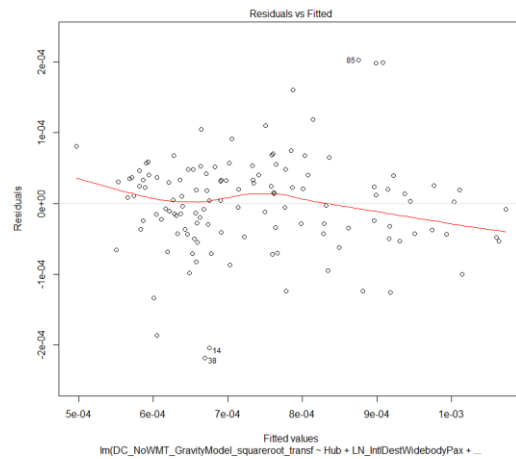
Normality (histogram of residuals)



Normality (q-q plots)



Heteroscedasticity (scatter plot of predicted values versus residuals)



**Figure 17. OLS assumptions for Model 1B.**



Models 1A and 1B closely conform with the OLS regression assumptions of homoscedasticity, normally distributed residuals, statistical independence of errors, and linearity of relationship, particularly after the transformations applied to the dependent and independent variables. Linearity is tested by examining a scatter plot of each variables' residuals against the dependent variables. Residuals are approximately normally distributed with minor leftward skew as evidenced in the histogram of residuals and q-q plots. Figure 16 and Figure 17 display plots supporting normality and homoscedasticity.

#### *5.4.2 FC Location Models*

The FC models measure the association of airport and regional traits with FC access. FC access is approximated via a gravity model that accounts for FCs' distance from the airport and each FC's floor area. FC access has two variants, one of which includes all FCs in the sample and the second of which excludes Amazon FCs. Amazon's size and level of development make it an outlier in e-fulfillment. A Box-Cox transform is applied to the FC access dependent variables, and most of the dependent variables have natural log transformations applied to decrease leftward skew. The following paragraphs describe model results, which are reported in detail in Table 13.

The models have high explanatory power, with  $R^2$ s well over 0.80. Regions with integrator air hubs are more central in FC networks than other airport regions, which suggests that e-retailers may seek warehouses central to integrator air or ground networks to serve as FCs. The shipper survey and logistician interviews measure FCs' use of integrator air or ground networks, and therefore these networks' potential influence on location choice.

Wide-body passenger aircraft have large bellyhold cargo capacity. E-retailers shipping from regions with many international air connections might access lower transportation prices or faster shipment times. However, the models do not find a statistically significant relationship between FC access and the number of international destinations accessible non-stop aboard wide-body passenger aircraft. The model may have insufficient statistical power (type II error), or the relationship may not exist. It is plausible that wide-body passenger aircraft do transport international e-retail shipments, but FCs do not cluster around international gateways and instead ship goods to gateways by air or ground modes.

Other flight variables are also tested and omitted from the reported results for reasons of insignificance and correlation with the included air network variables. The number of international destinations reachable non-stop by freighters was tested and omitted (p-value of 0.442 in Model 2A and 0.137 in Model 2B when substituted for international destinations served by wide-body passenger aircraft). The number of domestic destinations served non-stop by freighters was also tested and omitted (p-value of 0.843 in Model 2A and 0.400 in Model 2B). Finally, the last air network variable that was tested and omitted is the number of domestic destinations served non-stop by passenger aircraft excluding regional aircraft without cargo capacity (p-value of 0.565 in Model 2A and 0.969 in Model 2B). Integrator air hubs appear to influence FC location much more heavily than other parts of the air network.

There is moderate association between FC access and the ground transportation network, with increased highway density and access to seaports associated with FC access in Model 2B, but not in Model 2A. Neither model exhibits a relationship with railroad

density. Even though some past studies have identified an association between logistics activity and rail access (Cidell 2010), it is not expected to transfer to FCs because intermodal rail transports few consumer products or expedited shipments. Seaport access's significant and positive association with FC access in Model 2B is somewhat surprising considering that seaports nearly exclusively serve inbound shipments, which bear less conceptual significance in location choice than factors related to outbound shipments (Phillips 2017).

The most influential variables on FC access are associated with access to large customer bases, both regionally through the 'catchment population' variable and nationally through the 'distance to population center' variable. The catchment population variable describes the number of people that can be reached by overnight ground transport. Being near the national population center may be especially important for small e-retailers with one or two FCs to serve customers nationwide. The standardized coefficient for 'distance to population center' in Model 2B (FC access excluding Amazon) is higher than in Model 2A (FC access including Amazon) because Amazon's fulfillment network is tuned for regional distribution. The high cost of air transportation encourages e-retailers to locate FCs where as many customers as possible can be reached by surface modes.

While not statistically significant in Model 2A, labor costs are statistically significant in Model 2B. High regional labor costs depress airports' FC access. As expected, business environment is significantly and positively associated with greater FC access in Model 2B.

Table 13 displays results for Models 2A and 2B. A coefficient below zero reveals a positive relationship between the independent variable and FC access, while a coefficient above zero reveals a negative relationship, as indicated in the column titled “Association with DC Access.” Models 2A and 2B respect the assumptions of linear regression. Residuals are approximately normally distributed. Figure 18 and Figure 19 contain plots supporting linear regression assumptions, including a normally distributed histogram of residuals, q-q plots that are nearly linear, and scatter plots of predicted values versus residuals without clear trends.

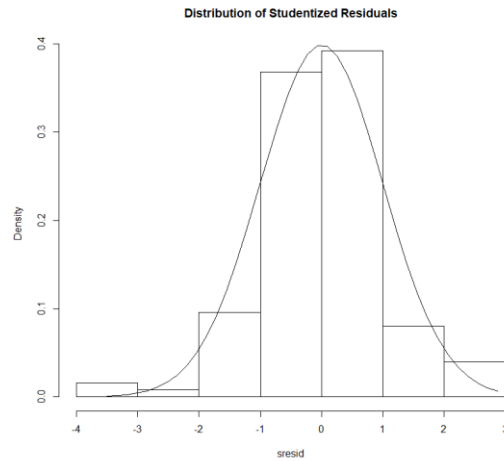
**Table 13. Results of FC location Models 2A and 2B.**

	Model 2A: Transformed FC access (all FCs)					Model 2B: Transformed FC access (all FCs except Amazon)				
	Coef.	Beta	Std. Error	Sig.	Association with FC Access	Coef.	Beta	Std. Error	Sig.	Association with FC Access
(Intercept)	4.3E-04	na	1.5E-04	0.01 ‡	na	-8.0E-04	na	0.01	0.93	na
<b>Integrator air hub (binary)</b>	<b>-1.1E-05</b>	<b>-0.10</b>	<b>4.3E-06</b>	<b>0.01 ‡</b>	<b>Positive</b>	<b>-6.6E-04</b>	<b>-0.10</b>	<b>2.7E-04</b>	<b>0.01 †</b>	<b>Positive</b>
LN(Destinations served by non-stop wide-body passenger aircraft)	-1.4E-07	-0.03	2.2E-07	0.52	Not detected	-9.4E-06	-0.03	1.4E-05	0.49	Not detected
<b>LN(Highway density)</b>	<b>-2.5E-06</b>	<b>-0.07</b>	<b>1.5E-06</b>	<b>0.10</b>	<b>Positive</b>	<b>-1.8E-04</b>	<b>-0.09</b>	<b>9.5E-05</b>	<b>0.06 *</b>	<b>Positive</b>
<b>LN(Containerized traffic index)</b>	<b>-3.3E-06</b>	<b>-0.08</b>	<b>2.1E-06</b>	<b>0.12</b>	<b>Positive</b>	<b>-2.7E-04</b>	<b>-0.12</b>	<b>1.3E-04</b>	<b>0.04 †</b>	<b>Positive</b>
Rail density	-1.1E-08	-0.04	1.1E-08	0.33	Not detected	-1.1E-07	-0.01	6.9E-07	0.87	Not detected
<b>LN(Catchment population)</b>	<b>-2.4E-05</b>	<b>-0.54</b>	<b>2.3E-06</b>	<b>0.00 ‡</b>	<b>Positive</b>	<b>-1.3E-03</b>	<b>-0.51</b>	<b>1.4E-04</b>	<b>0.00 ‡</b>	<b>Positive</b>
<b>Distance to population center</b>	<b>2.7E-08</b>	<b>0.50</b>	<b>3.1E-09</b>	<b>0.00 ‡</b>	<b>Negative</b>	<b>1.7E-06</b>	<b>0.56</b>	<b>1.9E-07</b>	<b>0.00 ‡</b>	<b>Negative</b>
<b>LN(Labor cost)</b>	<b>3.0E-06</b>	<b>0.01</b>	<b>1.5E-05</b>	<b>0.84</b>	<b>Not detected</b>	<b>2.8E-03</b>	<b>0.14</b>	<b>9.1E-04</b>	<b>0.00 ‡</b>	<b>Negative</b>
<b>Business environment</b>	<b>-2.2E-07</b>	<b>-0.03</b>	<b>3.7E-07</b>	<b>0.56</b>	<b>Not detected</b>	<b>-3.2E-05</b>	<b>-0.06</b>	<b>2.3E-05</b>	<b>0.00 ‡</b>	<b>Positive</b>

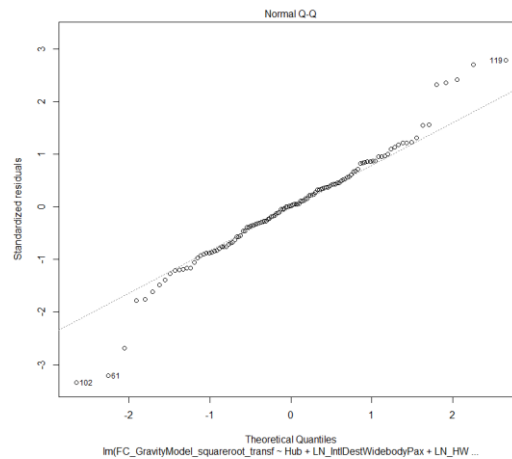
**R<sup>2</sup> for Model 2A: 0.851, n=127; R<sup>2</sup> for Model 2B: 0.830, n=125**

**‡ p< 0.01, † p< 0.05, \*p< 0.10**

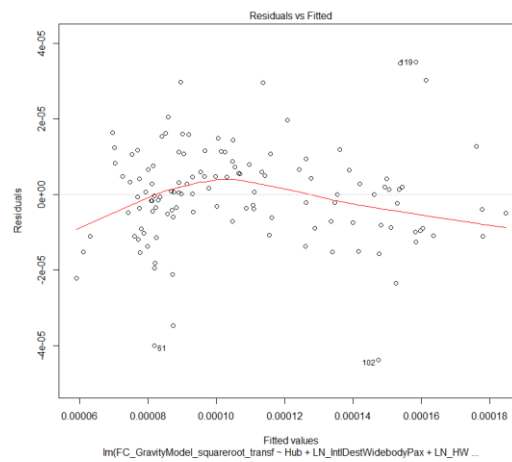
Normality (histogram of residuals)



Normality (q-q plots)

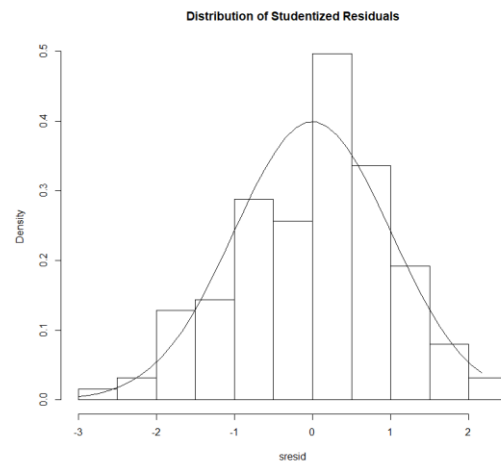


Heteroscedasticity  
(scatter plot of predicted values versus residuals)

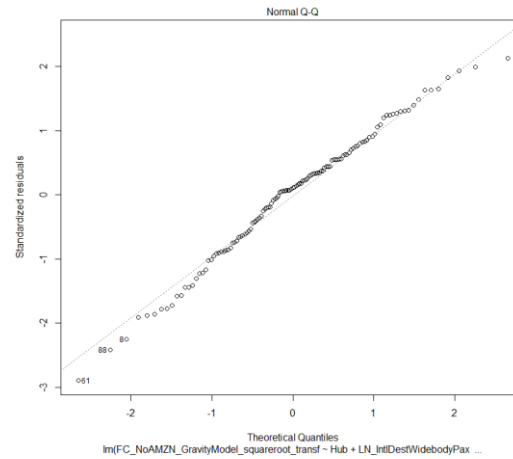


**Figure 18. OLS assumptions for Model 2A.**

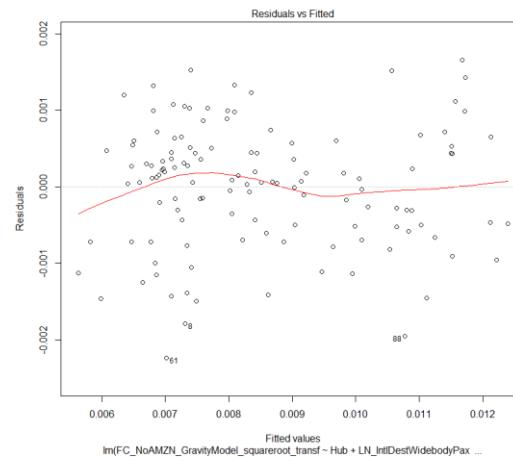
Normality (histogram  
of residuals)



Normality (q-q plots)



Heteroscedasticity  
(scatter plot of  
predicted values versus  
residuals)



**Figure 19. OLS assumptions for Model 2B.**

## 5.5 Conclusions from the Location Models

The models capture variation in DC and FC access very well, as evidenced by  $R^2$ s exceeding 0.80. Moreover, the relationships that the models uncover generally conform with theoretical expectations. Most divergences from theoretical expectations relate to a failure to confirm rather than an active contradiction, which may be attributable to insufficient statistical power. The models reveal the relationships that are the most conceptually important and statistically impactful. A small minority of relationships run counter to theory (28% in Models 1A and 1B, and 0% in Models 2A and 2B). Table 14 shows the variables conforming with theory in each model set, and Table 15 details theoretical expectations and results for each variable in each model.

**Table 14. Comparison of model results to theoretical predictions.**

	<b>Confirm Theoretical Expectations</b>	<b>Fail to Confirm Theoretical Expectations</b>	<b>Contradict Theoretical Expectations</b>
Models of DC access	8	5	5
Models of FC access	13	5	0



**Table 15. Summary of location model results.**

Category	Variable	DC - Expected direction	1A	1B	FC - Expected direction	2A	2B
Air connectivity	Integrator air hub	none	none	+	+	+	+
	International passenger destinations (wide-body)	none	-	-	+	none	none
Highway access	Highway density	-	none	none	+	none	+
Rail access	Rail density	+	none	+	none	none	none
Seaport access	Containerized traffic index	+	+	+	+	+	+
Customer proximity	Distance to population center (national)	+	+	+	+	+	+
	Catchment population (regional)	+	+	+	+	+	+
Business environment	State business friendliness	none	-	-	+	none	+
Costs	Labor costs	-	none	none	-	none	-

**Note:** Green: conform with theory; yellow: neither conform with nor against theory; red: against theory.

Results indicate a qualitative difference between integrator air hubs and other non-hub airports with high air cargo connectivity. Other airport traits add little explanatory power to either location model. Air connectivity independent of hubs has no association at all or even a negative association. Curfews are also insignificant in early model iterations and are omitted from the final model. The role of freighters and bellyhold capacity in e-fulfillment shipments merits further examination to understand the extent to which FCs use non-integrator air transport and the extent to which access to these carriers affects facility location. Warehouse locations for both sales channels are more associated with ground access to customers than with airport traits.

## **CHAPTER 6. E-FULFILLMENT NETWORKS**

### **6.1 Introduction**

In this chapter, a survey of e-retail and B&M retail shippers is used to estimate different regional traits' relative importance to DC and FC operations. Interviews with logistics experts supplement survey results. The surveys and interviews begin to trace the factors linked to operations and logistics network design that make a given regional trait important since they seek differences among the sales channels. Additionally, there exists variation within sales channels corresponding with other retailer characteristics, like retail sector and product types, number and location of stores, size of customer base, and facilities that are physical remnants of past logistics strategies.

Retail warehouses satisfy a very complicated set of tasks supporting physical distribution. They receive goods, hold inventory, and process outbound orders, all within retailers' lean logistics budgets. Workers in FCs and DCs disassemble inbound pallets and transfer items to inventory. When stock keeping units (SKUs) are requested by stores or customers, 'pickers' physically locate the items and consolidate them at a place where the entire order is packaged and loaded onto the right truck for delivery. The most automated facilities have electronic systems to pick and consolidate products. Shipments for stores are normally at the pallet-level, and shipments for online customers are composed of a small number of SKUs.

Despite these broad similarities, the exact nature of FCs' and DCs' missions differ in significant ways. DCs dispatch large shipments to stores. They have a relatively small

number of customers (dozens or hundreds of stores) making it possible to generate truckload shipments. DCs may also have more lead time to prepare orders because stores maintain cushion inventory. Additionally, it is easier to predict demand at the store level than at the customer level.

The e-retail sales channel has none of these aids. FCs process relatively small shipments destined for exponentially more locations. Orders are as small as one item or consist of many SKUs from multiple categories. Each order must nonetheless be separately consolidated, packaged, labeled, and loaded. The great number of customers impedes the construction of truckload shipments all ending near each other, which could increase the number of outbound truck movements. The lack of in-store inventory also removes the cushion between customers and FCs, so orders must be processed and shipments made particularly quickly.

Thus far, the dissertation's analysis has presented shippers' activity in abstract terms, devoid of specific spatial or strategic considerations. This simplistic presentation is not entirely accurate because regional traits influence shippers' operations. These regional traits include cost factors, location, accessibility to transportation infrastructure, regulations, proximity to customers and suppliers, and many others. The importance that shippers assign to each trait differs as a function of their operational needs. Shippers make trade-offs among regional traits on the land market since parcels rarely if ever exist with all the ideal traits. Regional traits occur above the parcel level, and therefore are essentially immune to shipper influence, so it is typically not possible to 'upgrade' a parcel that is lacking in one or more regional traits. Instead, shippers must find the land traits that they seek in fixed configurations on land markets and weigh different factors' relative value in

selecting a site. These trade-offs among regional traits produce different location patterns for facility types that share operational characteristics. FCs and DCs have different mission parameters, so they likely seek different regional traits to support their missions.

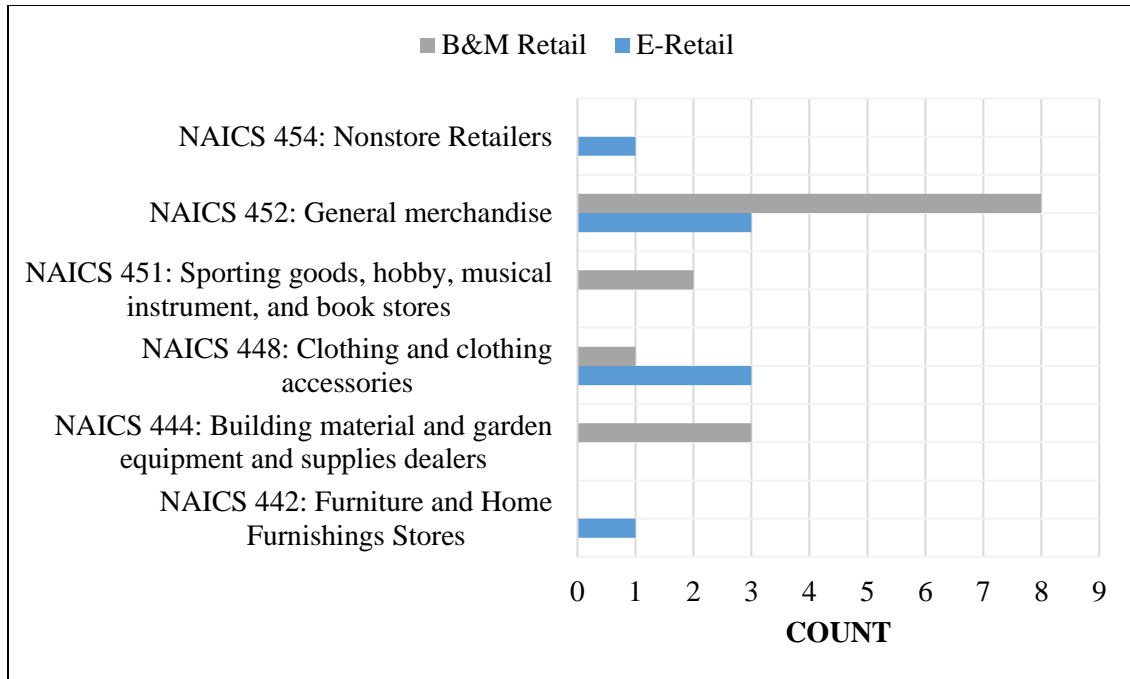
This chapter contains six sections in addition to the Introduction. The Respondents section compares the respondents' locations, size, and retail sectors with the entire sampling frame. Statistical tools are described and justified in the Statistical Approach section. The Results Summary section synthesizes the results for each question. The Detailed Responses section includes a thorough account of the results' relationship with theory. Interview results are documented in the Logisticians Interviews section. Finally, the Conclusions section is comprised of a synthesis of the survey and interviews.

## **6.2 Respondents**

The respondents represent a variety of sectors, locations, and firms of both sales channels. No more than one facility serving most retailers responded. The exceptions are a general merchandise retailer for which four DCs and two FCs responded, and a building materials retailer with two DC respondents. Retail sectors relate to the types of products that the retailer sells, whose value and physical characteristics determine viable shipping modes. Eleven of the 22 respondent facilities represent the general merchandise sector (NAICS 452), which involves selling a large variety of goods in settings that include 'big-box' retailers and department stores (Bureau of Labor Statistics 2017a). Three facilities process clothing and clothing accessories (NAICS 448), two facilities represent sporting goods (NAICS 451), one facility processes furniture and home furnishings (NAICS 442),

one is categorized as a nonstore [fashion] retailer (NAICS 454), and three facilities support retail sales of building materials (NAICS 444).

Respondents from the two sales channels are largely analogous in product types. DCs skew towards general merchandise more heavily than FCs (57% of DCs vs. 38% FCs). Twenty-one percent of DCs process building materials (NAICS 444), while 14% process sporting goods, hobby items, musical instruments, and books (NAICS 451). A higher proportion of FCs than DCs handle clothing (NAICS 338, 38% vs. 7%). The remaining FCs are split among furniture and home furnishings (NAICS 442), and non-store retailers (NAICS 454). Figure 20 displays the number of respondents that represent each retail sector. Notably absent from the sample is Amazon, which accounts for 63% of the FCs in the sample.



**Figure 20. Survey respondents by retail sector.**

The survey respondents are geographically distributed similarly to the sampling frame. Most FCs are in regions where FCs in the sampling frame cluster, like metropolitan Cincinnati, OH; Louisville, KY; Indianapolis, IN; and Dallas-Ft. Worth, TX. Respondent DCs mimic the DC sampling frame's pattern of dispersion, and rural and small-town concentration. Respondent DCs tend to be farther from major cities and airports than respondent FCs.

Twenty-two facilities representing 14 retailers responded to the survey. 5.3% of FCs responded, and 6.0% of DCs responded, for an overall response rate of 5.8%, which is roughly analogous to previous studies' response rates. A survey of warehouse managers in Arizona and northern Mexico elicited a response rate below 3% (InterVISTAS Consulting Group 2014). Response rates have been higher in other countries, near 20% in the Netherlands (Warffemius 2007a) and 16% in Canada (Jakubicek and Woudsma 2011).

In general, American businesses' response rates to surveys are "notoriously low" (Dennis 2003), and American businesses' survey response rates often fall below those of European businesses by around half (Harzing 1997). The retail sector's competitiveness and volatility may dissuade facility managers from sharing information for fear of inadvertently revealing business secrets. A researcher knowledgeable of the field describes the largest e-retailer as having a "we'll call you" mentality towards academic research [personal communication]. Secondly, several survey recipients referred to company policies prohibiting their response. Eliciting more responses from businesses often requires strategies such as phone follow-up that are not possible in this survey due to lack of facilities' phone numbers and email addresses (Dennis 2003).

### **6.3 Results Summary**

Responses are summarized below. Part A outlines the facilities' purpose and operations, including the proportion of shipments related to e-retail and geographic regions for which the facility is responsible. Part B explains the regional traits that matter for facilities' operations. Finally, Part C assesses outbound transportation choices to compare with regional traits' importance. The three tests identify several statistically significant differences between DCs and FCs, which are summarized. Table 16 displays test coefficients and statistical significant levels.



**Q3)** Facilities pre-identified as FCs process mostly e-retail shipments, and those pre-identified as DCs process mostly B&M shipments.

**Q4)** FCs are less likely to have a geographic focus than DCs.

**Q5a)** DC managers value low labor costs more than FC managers.

**Q5e)** FC managers value proximity to airports with cargo service more than DC managers. Beyond labor costs, proximity to airports, and proximity to highways, none of the regional traits register statistically significant differences among sales channels.

**Q5f)** DC managers value highway proximity more than FC managers.

**Q7a)** FC managers value the presence of multiple air cargo carriers at a nearby airport more than DC managers.

**Q7c)** FC managers value proximity to an integrator's air hub more than DC managers.

**Q8a)** FCs employ air as an outbound shipment mode much more frequently than DCs.

**Q8b)** DCs employ truckload (TL) transportation more often than FCs.

**Q9b and Q9c)** FCs employ integrators (Q9b) and the U.S. Postal Service (Q9c) more frequently than DCs.

**Q12)** FCs employ air as a transportation mode for next-day deliveries more frequently than DCs.

**Table 16. Statistical results.**

Question	Topic	ANOVA	Mann Whitney U Test	Independent Samples Median T-Test
<b>Q3</b>	<b>E-retail sales volume</b>	<b>0.00<sup>‡</sup></b>	<b>0.00<sup>‡</sup></b>	<b>0.00<sup>‡</sup></b>
<b>Q4</b>	<b>Geographic focus</b>	<b>0.00<sup>‡</sup></b>	<b>0.00<sup>‡</sup></b>	na
<b>Q5a</b>	<b>Your region: Low labor costs</b>	<b>0.03<sup>†</sup></b>	<b>0.05<sup>†</sup></b>	<b>0.06*</b>
Q5b	Your region: Low land costs	0.89	0.94	0.25
Q5c	Your region: Low business taxes	0.86	0.59	1.00
Q5d	Your region: Business-friendly regulation	0.56	0.59	0.65
<b>Q5e</b>	<b>Your region: Proximity to airport with cargo service</b>	<b>0.00<sup>‡</sup></b>	<b>0.01<sup>‡</sup></b>	<b>0.02<sup>†</sup></b>
<b>Q5f</b>	<b>Your region: Proximity to Interstate Highway</b>	<b>0.02<sup>†</sup></b>	<b>0.05<sup>†</sup></b>	0.16
Q5g	Your region: Low roadway congestion	0.25	0.26	0.16
Q5h	Your region: Proximity to seaport with cargo service	1.00	0.86	0.66
Q5i	Your region: Ability to use freight rail	0.50	0.59	0.62
Q5j	Your region: Proximity to suppliers	0.41	0.50	0.66
Q5k	Your region: Proximity to customers	0.12	0.15	na
<b>Q7a</b>	<b>Air system: Presence of many air cargo carriers at nearby airport</b>	<b>0.00<sup>‡</sup></b>	<b>0.00<sup>‡</sup></b>	<b>0.01<sup>‡</sup></b>
Q7b	Air system: 24-hour airport operations	0.14	0.27	0.36
<b>Q7c</b>	<b>Air system: Proximity to air hub for express parcel carriers</b>	<b>0.00<sup>‡</sup></b>	<b>0.00<sup>‡</sup></b>	0.17
<b>Q8a</b>	<b>Outbound shipment modes: Air</b>	<b>0.00<sup>‡</sup></b>	<b>0.00<sup>‡</sup></b>	<b>0.00<sup>‡</sup></b>
<b>Q8b</b>	<b>Outbound shipment modes: Truckload ('TL')</b>	<b>0.00<sup>‡</sup></b>	<b>0.04<sup>†</sup></b>	na
Q8c	Outbound shipment modes: Less than truckload ('LTL')	0.72	0.74	1.00
Q8d	Outbound shipment modes: Rail	0.35	0.59	0.62
Q9a	Outbound shipment carriers: Trucks owned, leased, or operated by this facility	0.28	0.35	1.00
<b>Q9b</b>	<b>Outbound shipment carriers: Express parcel carriers</b>	<b>0.01<sup>†</sup></b>	<b>0.02<sup>†</sup></b>	na
<b>Q9c</b>	<b>Outbound shipment carriers: U.S. Postal Service</b>	<b>0.00<sup>‡</sup></b>	<b>0.00<sup>‡</sup></b>	<b>0.00<sup>‡</sup></b>
Q9d	Outbound shipment carriers: Other third-party logistics providers	0.25	0.32	na
Q10	Next-day deliveries	0.87	0.74	0.49
Q11	Next-day delivery schedule	0.21	0.14	0.10
<b>Q12</b>	<b>Next-day delivery modes</b>	<b>0.03<sup>†</sup></b>	<b>0.03<sup>†</sup></b>	0.32

<sup>‡</sup> p < 0.01, <sup>†</sup> p < 0.05, \*p < 0.10; na: not available.

## 6.4 Detailed Responses

In Part A, respondents identify their sales channel, operation types, and geographic areas of responsibility. The answers provide the foundation for understanding facilities' missions.

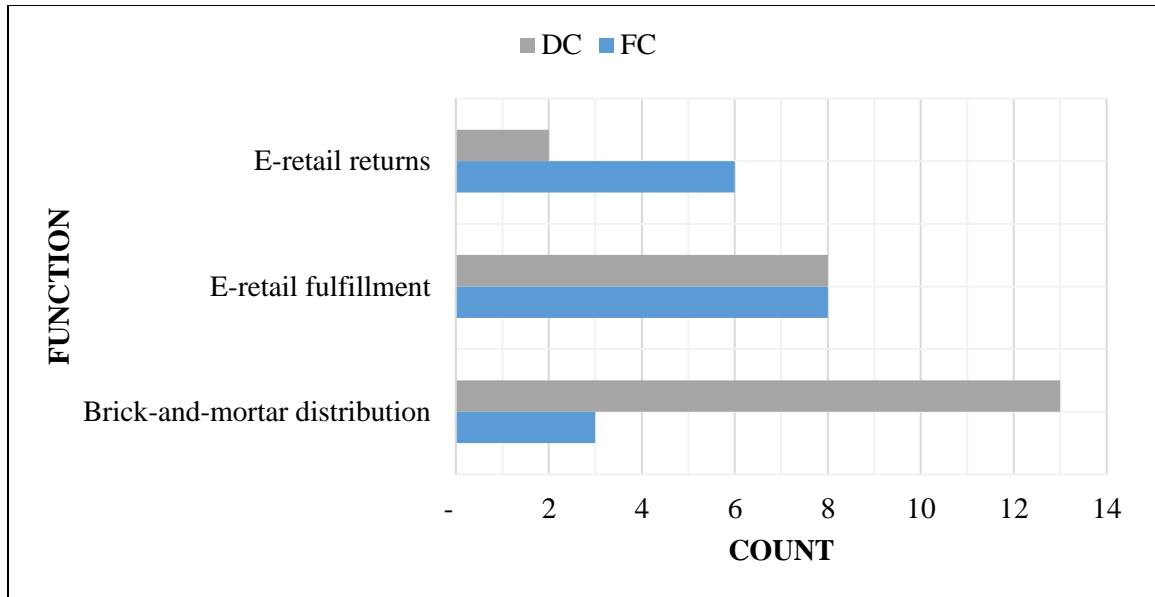
### 6.4.1 *Part A: Facility Operations*

#### 6.4.1.1 Q1) Retail logistics: Is your facility involved in retail logistics, regardless of sales channel?

One survey was returned from a facility that is not involved in retail logistics. It is not counted as a response to any of the future questions, nor is it counted in calculating the response rate.

#### 6.4.1.2 Q2) Functions: Which of the following functions are applicable to your facility?

Facilities' functions are shown in Figure 21. Only three FCs perform any functions supporting B&M retail. A subsequent interview with one such FC manager revealed B&M retail shipments to be small in scale and seasonal. By contrast, around half of DCs process a small amount of shipments for online customers. Most FCs also process e-retail returns, as do two DCs.



**Figure 21. Facility functions.**

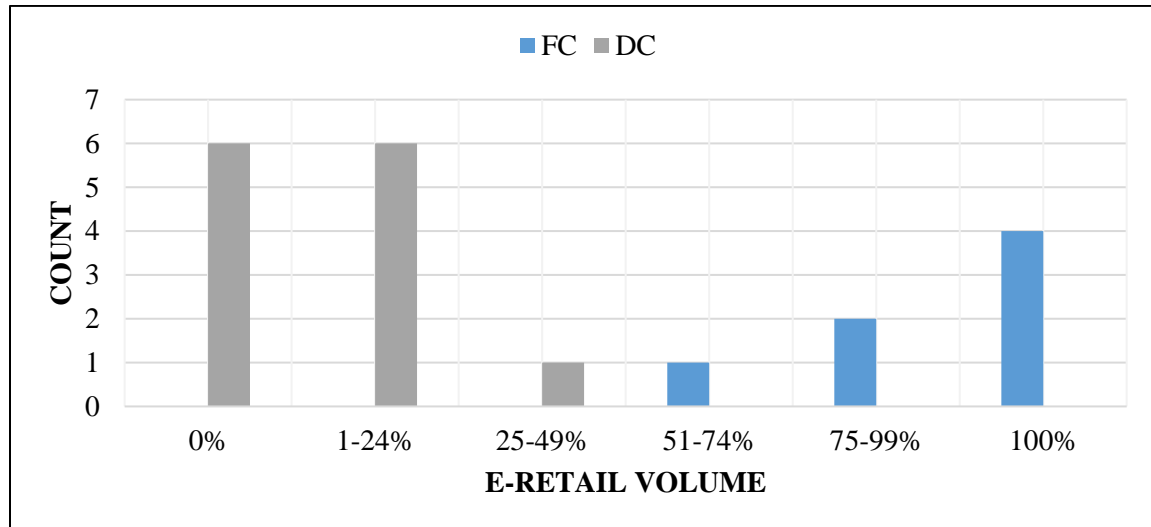
**Number of respondents (n): FCs = 8; DCs = 14.**

6.4.1.3 Q3) E-retail sales volume: Approximately what percentage of your outbound shipment volume is associated with e-retail sales?

**Statistically significant difference:** The warehouses pre-identified as FCs process higher e-retail shipment volumes than facilities pre-identified as DCs, signifying that facilities' sales channels were correctly identified. [tests: ANOVA, Mann Whitney U, Independent Samples Median]

Figure 22 reports the percentage of shipments that support e-retail by pre-assigned facility type. The strong divergence between DCs and FCs indicates that facilities' sales channels are correctly pre-identified. Over half of DCs report some e-fulfillment activity in their facility, normally accounting for between 1% and 24% of shipments. Fewer than

half of facilities that process any e-fulfillment also handle e-retail returns. This suggests that retailers may consolidate returns into specialized facilities or a smaller number of FCs.



**Figure 22. E-retail sales volume.**

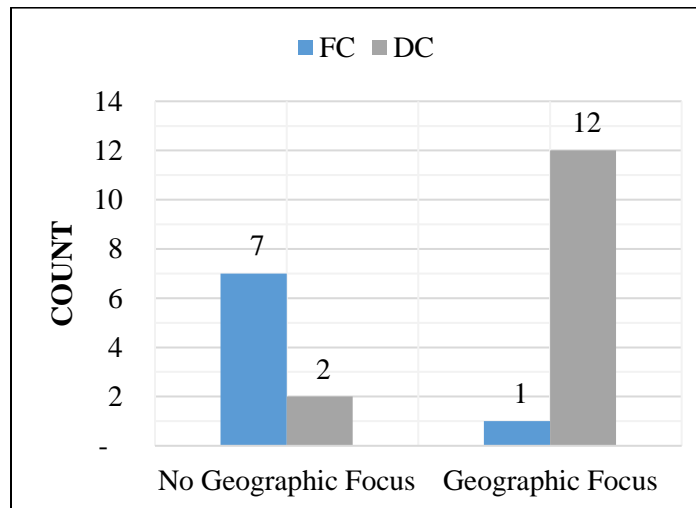
**Number of respondents (n): FCs = 7; DCs = 14.**

6.4.1.4 Q4) Geographic focus: Does your facility serve stores or customers in a specific part of the country?

**Statistically significant difference:** DCs are more likely to have a geographic area of responsibility than FCs. [tests: ANOVA, Mann Whitney U]

Figure 23 reports the percentage of facilities by sales channel with a defined geographic area of responsibility. All DCs except one have a geographic area of responsibility comprised of several states, while most FCs report no geographic focus. The sole FC that reports a geographic area of responsibility belongs to a company with multiple

FCs, which may allow it to assign areas of responsibility to FCs in a way that is impractical for smaller e-retailers.



**Figure 23. Geographic focus.**

**Number of respondents (n): FCs = 8; DCs = 14.**

#### *6.4.2 Part B: What Does Your Facility Need from a Region?*

Part B asks respondents about the regional traits that may contribute to their facility's optional success. These traits may reveal the regions that are intrinsically most attractive to retail warehouses of either sales channel.

##### 6.4.2.1 Q5) Your region: How important are the following state or regional traits for the success of your operations?

**Statistically significant differences:**

DCs attribute greater importance to low labor costs than FCs. [tests: ANOVA, Mann Whitney U, Independent Samples Median]

FCs attribute greater importance to cargo airport proximity than DCs. [tests: ANOVA, Mann Whitney U, Independent Samples Median]

DCs attribute greater importance to Interstate Highway proximity than FCs. [tests: ANOVA, Mann Whitney U]

Each regional trait is discussed in decreasing order of importance to FC managers.

**Customer proximity (1<sup>st</sup> most important trait for FCs, 4<sup>th</sup> for DCs):** FC managers most greatly value customer proximity, which is expected given e-retailers' increasingly pronounced need to deliver orders quickly.

**Business-friendly regulation (2<sup>nd</sup> most important trait for FCs, 3<sup>rd</sup> for DCs):** Differences in overall tax burden, labor laws, and building and permitting could affect operations' viability.

**Cargo airport proximity (3<sup>rd</sup> most important trait for FCs, 11<sup>th</sup> for DCs):** The importance of proximity to an airport with air cargo service pertains to many FCs' need to reach a dispersed customer base quickly. Cargo airport proximity could be especially important for small or emerging e-retailers because they have few FCs and may therefore require fast transportation to reach the farthest customers.

**Low business taxes (4<sup>th</sup> most important trait for FCs, 5<sup>th</sup> for DCs [tie]):** E-retail's fourth-highest rated regional trait is low business taxes. This trait mimics business-friendly regulation.

**Low land costs (5<sup>th</sup> most important trait for FCs [tie], 5<sup>th</sup> for DCs [tie]):** Taxes and land costs both add expense to the logistics network. While the e-fulfillment industry's high average transportation costs might motivate FCs to minimize land costs, the rapidly growing sales channel is prioritizing other regional traits.

**Highway proximity (5<sup>th</sup> most important trait for FCs [tie], 1<sup>st</sup> for DCs):** Nearly all past studies on warehouse location have highlighted highway proximity as one of the factors attracting warehouses. Highways' near ubiquity provides warehouses with many possible sites, allowing other regional traits to assume a more decisive role.

**Low labor costs (7<sup>th</sup> most important trait for FCs, 2<sup>nd</sup> for DCs):** FC managers rate low labor costs to be mildly important to their operations. This moderate rating of importance is despite the fact that FCs' work is routinely more labor-intensive than DCs' work because of small shipment sizes.

**Road congestion (8<sup>th</sup> most important trait for FCs, 7<sup>th</sup> for DCs):** Roadway congestion is the third least important regional trait for FCs' operations.

**Proximity to suppliers (9<sup>th</sup> most important trait for FCs, 8<sup>th</sup> for DCs):** FC managers rate supplier proximity as relatively unimportant to their operations. The assessment of low importance supports the notion that e-retailers select FC location based more heavily on customer-related factors and outbound transportation than supplier factors and inbound transportation.

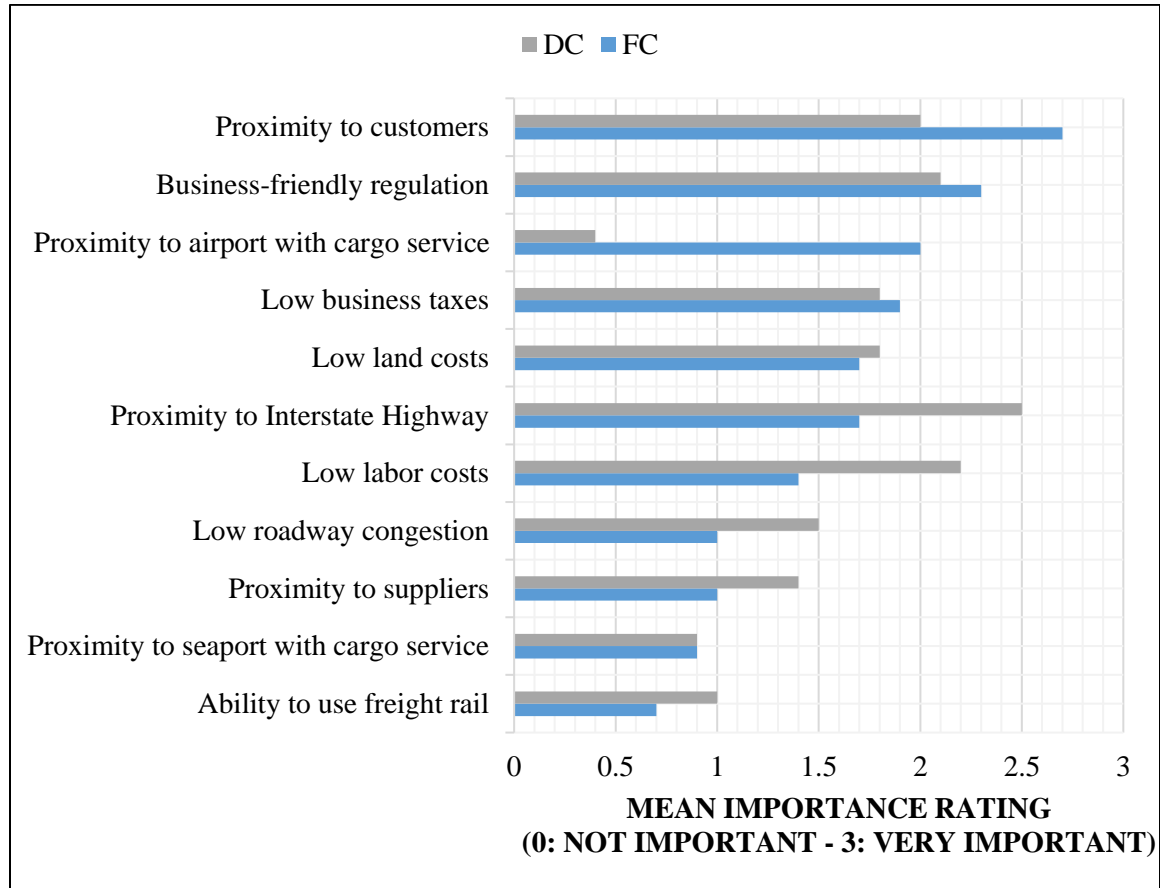


**Seaport proximity (10<sup>th</sup> most important trait for FCs, 10<sup>th</sup> for DCs):** FC managers rate seaport proximity as the second least important factor to their operations. Although many goods sold by e-retailers are imported, it is more important to be near the customer because outbound transportation is more expensive and time-sensitive than inbound shipments. Waterborne transportation rarely serves outbound e-retail shipments unless overseas customers are willing to wait several weeks between item purchase and delivery.

**Rail proximity (11<sup>th</sup> most important trait for FCs, 9<sup>th</sup> for DCs):** FCs' least important regional trait is freight rail. Despite intermodal rail's growth in certain freight segments, it is not a viable mode for most outbound e-retail shipments.

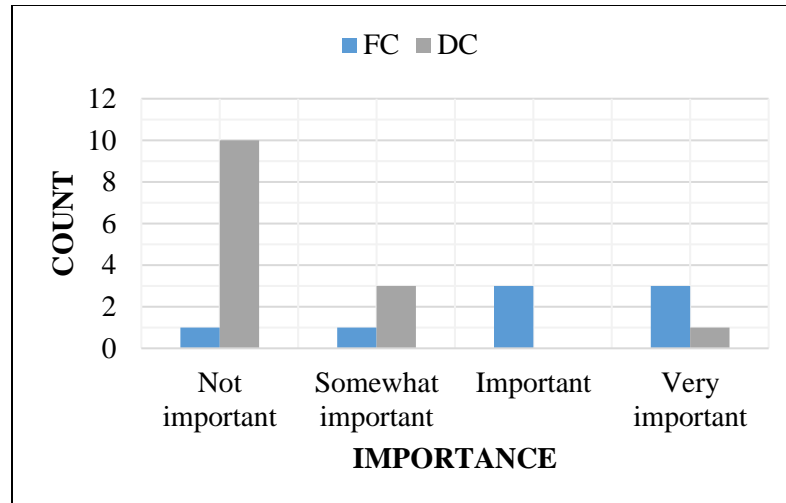
DC and FC managers assess most regional traits' importance similarly. Airport proximity is the largest exception. FC managers value airport access much more than DC managers. Only one DC manager out of 14 rates airport proximity as 'very important,' while three FC managers out of seven do so, and two additional FCs rate it as 'important.' Ten out of 14 DC managers report that airport proximity is 'not important,' which only one FC manager does. DC managers also describe low labor costs as more important than FC managers, which is counter-intuitive because FCs' operations are routinely more labor-intensive than DCs' (Bjorson 2013). A plausible explanation is that e-retailers may be more interested in long-term market share than short-term profitability, rendering costs subservient to service. The third statistically significant difference is in proximity to Interstate Highways, which DC managers report to be more important than FC managers. Most other regional traits are rated similarly by manager of both sales channels. Figure 24

reports complete results, and Figure 25 dissects respondents' ratings of airport proximity's importance.



**Figure 24. Mean importance of regional traits to FC and DC managers.**

**Number of respondents (n): FCs = 8 for “proximity to airport with cargo service” and 7 for others; DCs = 14.**



**Figure 25. Importance ratings of “proximity to airport with cargo service.”**

**Number of respondents (n): FCs = 8; DCs = 14.**

6.4.2.2 Q6) Airports & air carriers: Do your operations utilize an airport or air carrier for outbound transportation either fully or partially? Please briefly specify which one(s) and by how much.

This free response question asks respondents to identify airports or air carriers of importance their operations. FCs generally have closer relationships than DCs with an airport in their region and with one or more carriers, typically including an integrator. Two FC managers and ten DC managers indicate that “air transport does not play a role in facility operations.”

All FCs except one are in the same metropolitan area as an integrator air hub, and all are located within at least a few dozen kilometers of a commercial airport. The manager at a clothing and fashion FC several dozen kilometers from Louisville International Airport (SDF, a UPS hub) describes a partnership with UPS for air-shipped packages. Moreover, FCs do not collaborate exclusively with the hub airline at the nearest commercial airport.

For instance, a general merchandise FC near Indianapolis, IN splits its air cargo between the hub airline (FedEx) and the non-hub airline (UPS). FedEx receives approximately two thirds of the volume, and UPS receives the remainder.

The airport that most affects the facility's operations may not be the closest commercial airport. For instance, the manager of an FC located a few kilometers from Fort Worth Alliance Airport (AFW, a FedEx hub) reports that it is instead the UPS hub at Dallas-Fort Worth International Airport (DFW) over 30 km away that is its most important airport connection. Moreover, it is not mandatory for an FC to be near an air hub to frequently use air services. The manager of an FC near Fort Lauderdale-Hollywood International Airport (FLL) reports a relationship with FedEx even though the airport does not host a cargo hub.

Airports sometimes find unique entry points into B&M retail logistics networks. For instance, an apparel DC in central California uses air shipment primarily to transport goods to Hawaii. Items are transported by truck 300 km to Los Angeles International Airport (LAX), where they are loaded aboard aircraft for shipment to Hawaii. The DC could conceivably transport goods through the commercial airport in its hometown, but it has decided instead to use a larger airport with greater service offerings. Not surprisingly, the manager of this DC rated airport proximity as unimportant. Conversely, some DCs use air for inbound rather than for outbound shipments, such as a general merchandise DC in Fort Worth, TX that uses DFW airport 40 km away for at least some inbound shipments.

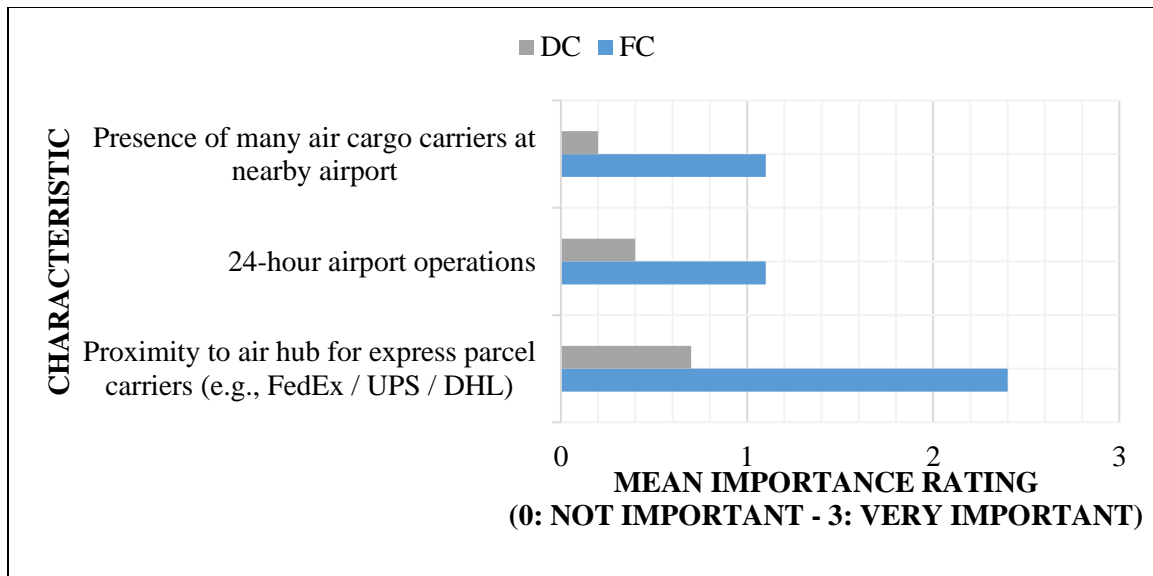
In summary, the difference between the sales channels supports the alternative hypothesis of a new e-fulfillment relationship with airports, especially integrator air hubs.

E-retailers often establish FCs near a commercial airport, usually in the same region as an integrator air hub. The FC often contracts with the integrator and other air carriers for outbound shipments. Contrarily, DC managers do not regularly use airports or air carriers in their outbound operations.

6.4.2.3 Q7) Air system: Do the following matter to your business operations?

**Statistically significant difference:** FC managers attribute greater importance to the presence of many air cargo carriers and proximity to an integrator air hub than DC managers. [tests: ANOVA, Mann Whitney U]

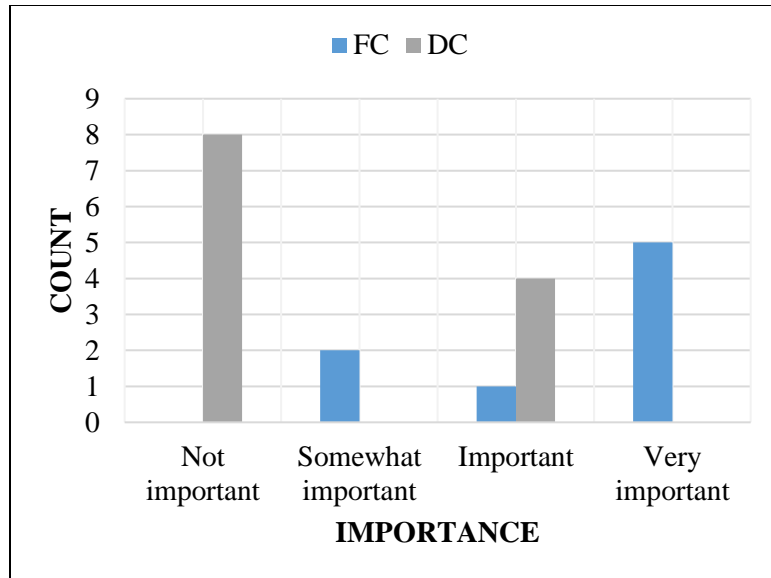
Airports' value to warehouse managers derives from their ability to provide access to the air system. Consequentially, airports' value may vary as a function of its air system attributes. This question probes the influence of traits of the air system on a region's attractiveness to retail warehouses. The three traits are the presence of multiple air cargo carriers, which may lower freight rates and hasten delivery; 24-hour airport operations, which may extend facility working hours; and the presence of an integrator air hub, which may delay next-day shipping cutoffs. Figure 26 displays the three attributes' average importance ratings, which are explained in the following paragraphs.



**Figure 26. Mean importance of air system attributes.**

**Number of respondents (n): FCs = 8; DCs = 12.**

The greatest divergence in importance ratings between the sales channels concerns integrator air hubs (descriptively called “express parcel carriers” in the survey). Proximity to an integrator air hub matters more to FC managers than the other air system traits, and statistical tests differentiate FCs’ and DCs’ mean ratings. As visible in Figure 27, five out of seven FC managers assess integrator air hub proximity to be either ‘very important’ (x4) or ‘important’ (x1). By contrast, eight out of 14 DC managers rate integrator air hub proximity ‘not important.’ Of the four DC managers assessing integrator air hubs to be ‘somewhat important,’ two previously indicated using air transport for inbound shipments or outbound transportation to island-based stores. FC managers routinely rate the level of competition among carriers and 24-hour airport operations as somewhat important, while DC managers rate them as unimportant.



**Figure 27. Mean importance of proximity to integrator air hub (“express parcel carriers”).**

**Number of respondents (n): FCs = 8; DCs = 12.**

#### 6.4.3 Part C: Outbound Transportation

Part C investigates outbound transportation modes and carriers. FCs’ and DCs’ different missions and valuations of regional traits’ importance are expected to reflect in their choice of carriers and modes. Questions 8 and 9 pertain to all outbound shipments, while questions 10 through 13 pertain to e-retail shipments made from FCs or DCs.

6.4.3.1 Q8) Outbound shipment modes: Outbound shipments are those that move from your facility to customers or stores. How often are the following modes used for all or a segment of outbound delivery routes?

**Statistically significant differences:**

FCs employ air transportation for outbound shipments more frequently than DCs.

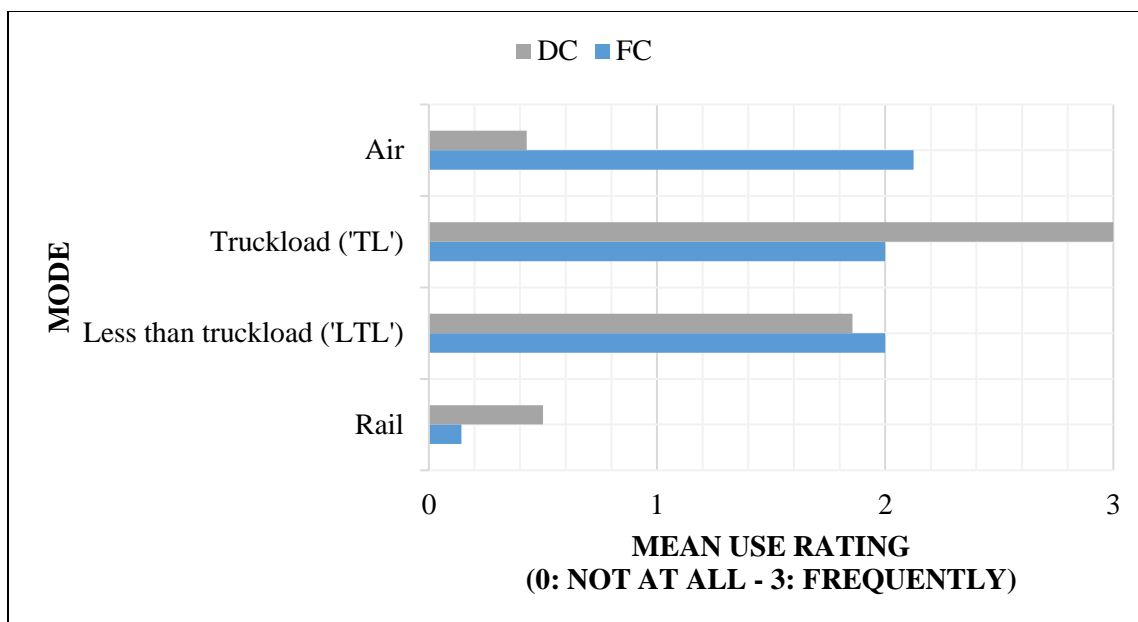
[tests: ANOVA, Mann Whitney U, Independent Samples Median]

DCs employ truckload transportation for outbound shipments more frequently than

FCs. [tests: ANOVA, Mann Whitney U]

Retailers' choice of transportation mode is a function of customers' location, delivery requirements, shipment size, and item value among other factors. The two sales channels encounter these factors in different configurations, so it is unsurprising that survey respondents report differences in outbound transportation related to the sales channels. Figure 28 summarizes the respondents' usage of outbound transportation modes. FCs employ air transportation so much more frequently than DCs that all three statistical tests detect the difference. FC managers report hiring air, truckload (TL) and less than truckload (LTL) shipments at similar rates, while rail rarely serves outbound shipments of either sales channel.





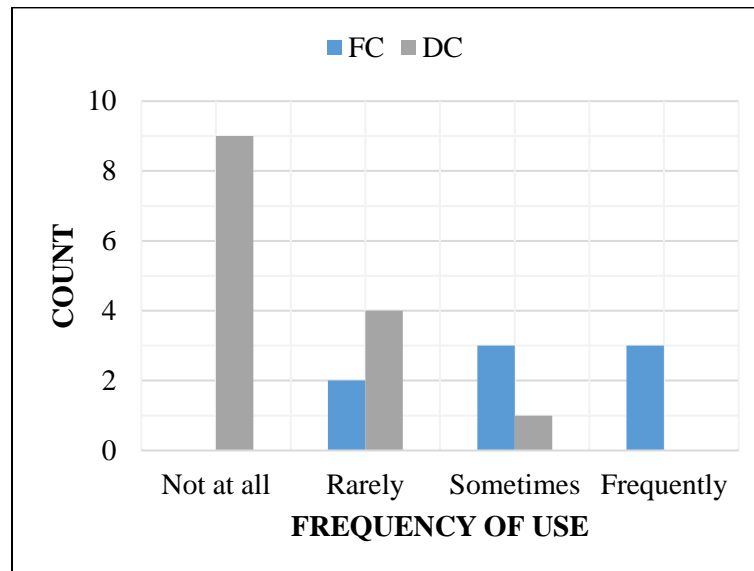
**Figure 28. Frequency of use of modes for outbound transportation.**

**Number of respondents (n): FCs = 8 for “air” and 7 for others; DCs = 14.**

DCs rely most heavily on truckload (TL) transportation, which is frequently used by all 14 DCs. DCs also sometimes employ LTL transportation. DCs’ greater use of truckload shipments compared with FCs likely reflects larger shipment sizes and proximity to multiple stores, which allows consolidation of shipments into fewer, larger vehicles than is practical when shipments are small and destinations widely dispersed. The average DC uses air transport much less frequently than the average FC, a difference that is expected because shipments to stores are rarely time-sensitive enough to justify air transport’s high cost. Rail plays a negligible role in FCs’ outbound transportation. All FCs except one and nine DCs out of 14 do not use rail at all.

Figure 29 summarizes air transport use by sales channel. All FCs use air transport, and several use it frequently. By contrast, nearly all DCs never or only rarely use air transport. Nine out of 14 DCs do not use air transport for any outbound shipments. The

sole DC manager that reports ‘sometimes’ using air transport previously reported using air “primarily for inbound import shipments.” There is no apparent pattern between frequency of air shipment and proximity to integrator air hubs.



**Figure 29. Use of air as a mode for outbound transportation.**

**Number of respondents (n): FCs = 8; DCs = 14.**

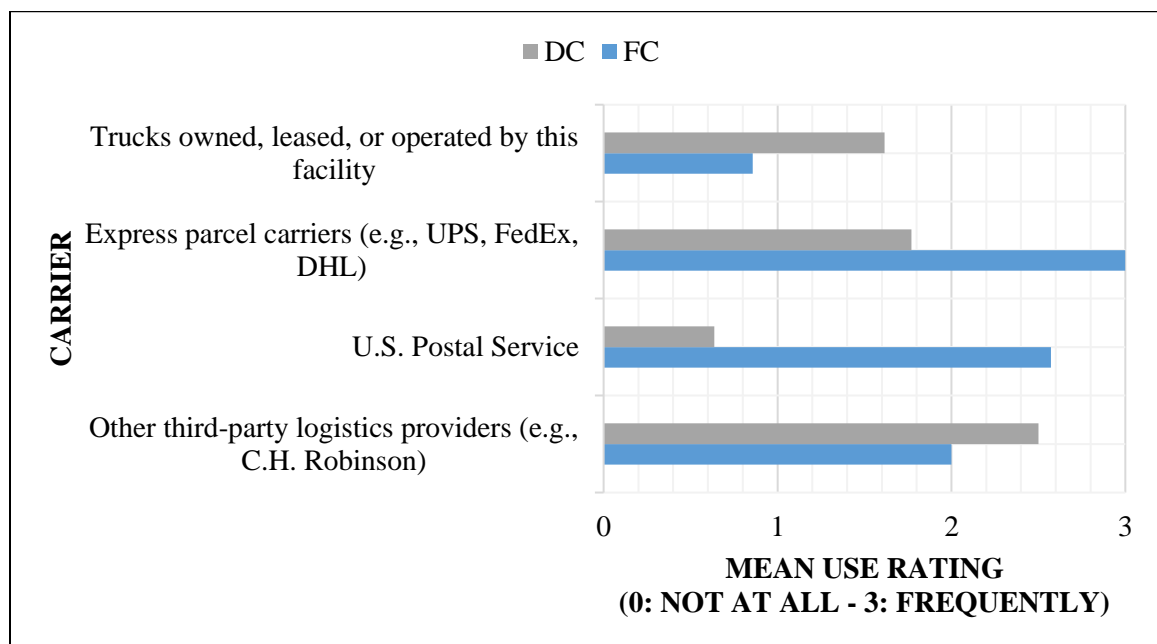
6.4.3.2 Q9) Outbound shipment carriers: How often are the following carriers used for outbound shipments?

**Statistically significant differences:**

FCs use integrators for outbound shipments more frequently than DCs. [tests: ANOVA, Mann Whitney U]

FCs use the U.S. Postal Service for outbound shipments more frequently than DCs. [tests: ANOVA, Mann Whitney U, Independent Samples Median]

Modes and carriers are distinct. Many carriers may operate a given mode, and some carriers operate several modes. Theory suggests that e-retail shipments will favor outbound modes that specialize in rapid, door-to-door delivery of small parcels, like integrators and USPS. By contrast, DCs are expected to prefer in-house trucking and 3PLs. The survey confirms the expectation. FCs favor integrators and USPS, while DCs prefer to use 3PLs, hire integrators, or operate their own trucks. Figure 30 reports carrier use by sales channel.



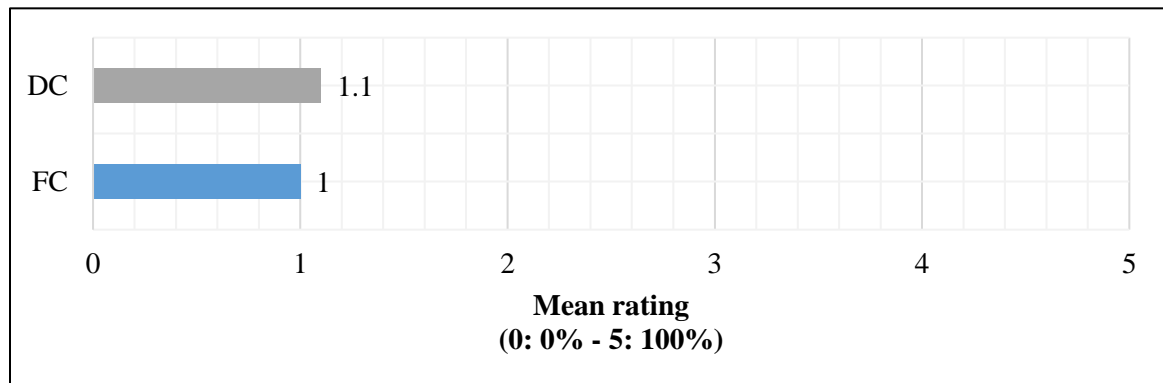
**Figure 30. Frequency of use of carriers for outbound transportation.**

**Number of respondents (n): FCs = 7; DCs = 13.**

FCs ship goods primarily with integrators (i.e., “express parcel carriers”) and secondarily with USPS. All FCs report using integrators frequently, versus a third of DCs. All FCs use USPS either frequently or sometimes, whereas few DCs use USPS at all. DCs ship most frequently with 3PLs, and secondarily with integrators.

6.4.3.3 Q10) Next-day deliveries: What percentage of your e-retail shipments require next-day delivery?

Managers of retail warehouses that process e-retail sales regardless of primary sales channel are asked to estimate next-day deliveries as a proportion of their shipments. Next-day deliveries are among the most time-sensitive delivery categories. Next-day delivery requires air transport when the destination is too far from the warehouse for ground transport. Most retail warehouses process a robust minority of e-retail orders as next-day shipments. The mean rating is nearly identical for DCs and FCs, with between 1% and 24% of all orders made online requiring next-day delivery (Figure 31).



**Figure 31. Mean portion of orders made online that require next-day delivery according to primary facility type.**

**Number of respondents (n): FCs = 7; DCs = 10.**

6.4.3.4 Q11) Next-day delivery schedule: By what time must your e-retail packages be transferred to the carrier to arrive by the next day (i.e. “drop-off time”)?

**Note for Q11) Number of respondents (n): FCs = 7; DCs = 7.**

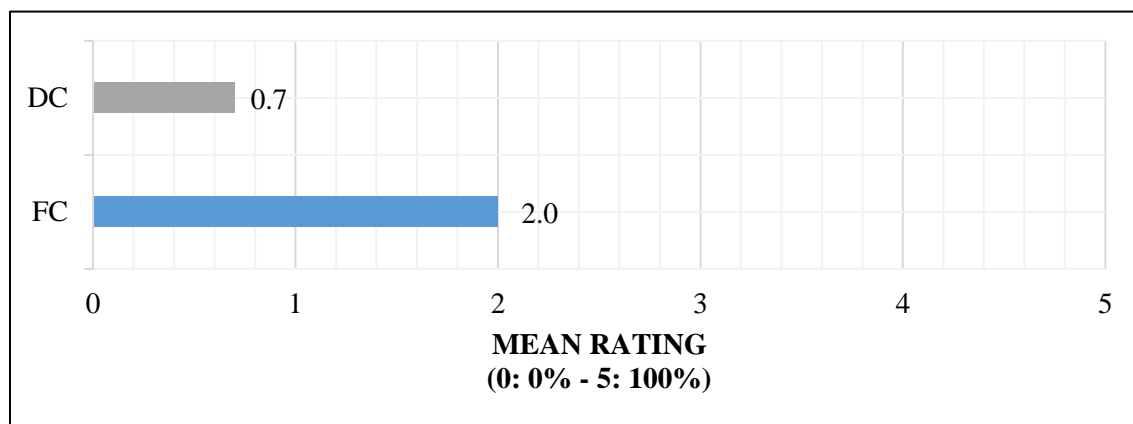
One reason that e-retailers may be attracted to sites near integrator air hubs is that the proximity allows them to extend their working day by delaying their drop-off time to carriers for next-day delivery. Shipping from hubs avoids the need to transport goods to the hub earlier in the night for mid-night connections (Kasarda and Lindsay 2011). FCs' disproportionate location near integrator air hubs is expected to result in later drop-off times compared with DCs. The results support the hypothesis that FCs have later drop-off times than DCs, and that proximity to integrator air hubs may explain part of the difference. The median FC drop-off time is nearly three hours later (7:15 PM) than the median DC drop-off time (4:30 PM). The latest FC drop-off time is 11 PM (for an FC adjacent to Cincinnati/Northern Kentucky International Airport), while the latest DC drop-off time is 6 PM. The results are not definitive since the response rate is especially low, opening the possibility of selection bias.

6.4.3.5 Q12) Next-day delivery modes: What percentage of next-day deliveries are transported by air?

**Statistically significant difference:** FCs use air transport for next-day deliveries more frequently than DCs. [tests: ANOVA, Mann Whitney U]

FCs employ air transport more frequently for next-day deliveries than DCs. The median FC uses air transport for between 1% and 24% of outbound next-day shipments. All FCs use air for at least some outbound next-day shipments, and one FC even uses air for between 75% and 99% of outbound next-day shipments. By contrast, several DCs do not use air for any next-day shipments, while the one DC that is adjacent to an integrator air hub ships between half and three quarters of its next-day deliveries by air. There is a

statistically significant difference between DCs' and FCs' mean frequency. A plausible explanation of the difference relates to logistics network size. Many respondent e-retailers operate a small number of FCs. Their scale and spatially concentrated inventory may require air transport to compensate for operating only a few inventory locations. By contrast, most respondent DCs are part of larger networks, which may allow the retailer to assign online orders to warehouses near the customer to minimize expensive air transport.



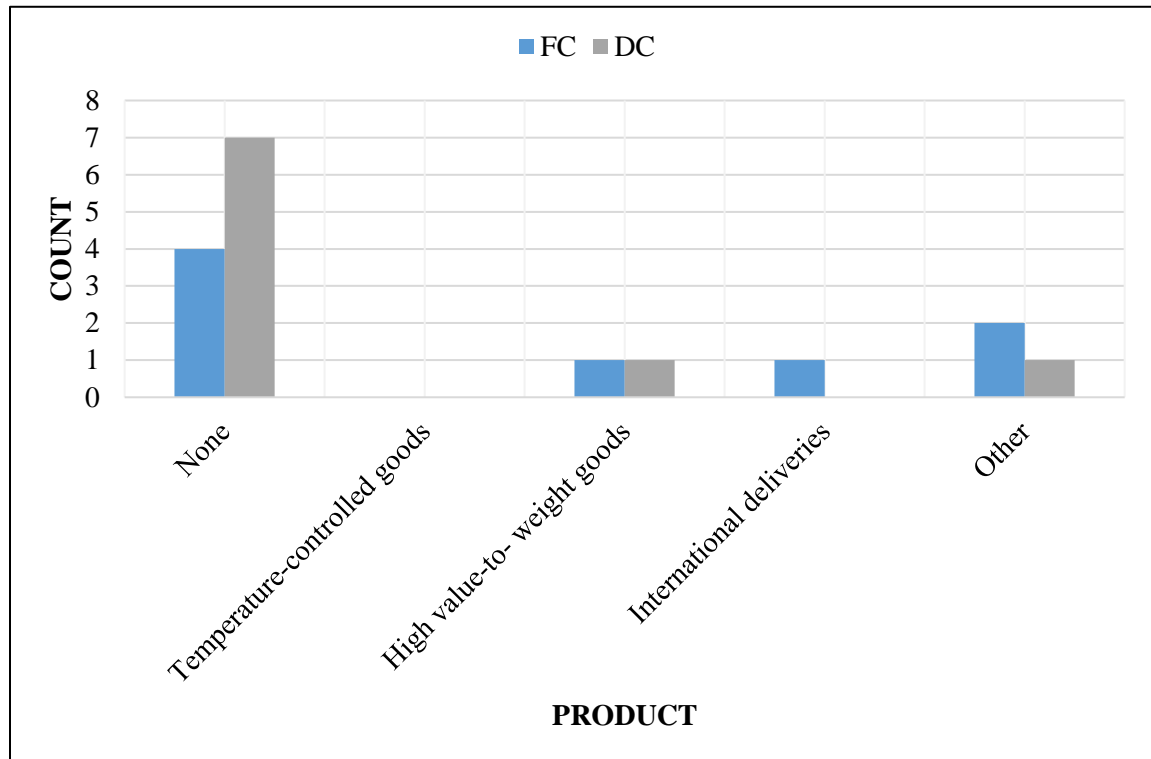
**Figure 32. Mean portion of next-day e-retail deliveries moved by air according to primary facility type.**

**Number of respondents (n): FCs = 8; DCs = 16.**

6.4.3.6 Q13) Product air deliveries: Excluding next-day deliveries, which of the following products are generally delivered by air? (select all that apply)

It is useful to understand the product types that are most frequently transported by air to hypothesize motivations for the mode choice. The survey asks if several types of goods favor air transport. There is no apparent pattern between product type and air shipment. Several facilities report that either high-value goods or international shipments may move by air, and some also report shipping “other” expedited goods by air.

Respondents describe “other” products as relating to a specific customer request for expedited delivery rather than a product type. Delivery urgency motivates air transport more than product type.



**Figure 33. Products beyond next-day shipments generally requiring transport by air.**

**Number of respondents (n): FCs = 8; DCs = 10.**

**‘Other’ generally refers to customer requests for expedited delivery.**

## **6.5 Interviews**

The interviews are analyzed in three categories that align with the survey’s organization. The first is Logistics Strategy, which relates to system-level decisions forming a fulfillment network (e.g., assignment of orders to FCs). The Logistics Strategy

theme relates to Part A of the survey (Facility Operations). The second theme is Regional Factors, which relates to Part B of the survey (Regional Traits). It describes regional traits that FCs may seek in location choice. Outbound Transportation is the third theme (related to survey Part C), and it investigates reasons for which an e-retailer might select one outbound transportation mode over another. Subsequent subsections detail results corresponding with each theme.

#### *6.5.1 Logistics Strategy*

In e-retail's early stages, many e-retailers adopted a strategy of national distribution from a single FC. As e-retail grew, a 'four corners' strategy gained prominence by allowing faster and cheaper delivery. Most recently, some e-retailers, notably Amazon, have moved towards regional or even metropolitan fulfillment models. The regional approach establishes FCs to serve regions with major customer bases, starting with those with the greatest population and market area. The regional approach has also seen the development of small FCs in urban areas as staging points for products requiring extremely fast delivery (Fung 2017). Each strategy privileges different regional traits in warehouse location choice. As sales volume grows, it becomes economical to forward locate inventory in more regions.

The industry has shifted towards regional e-fulfillment strategies in part due to the industry's competitive nature, which—pushed by Amazon—is adopting tighter delivery schedules. Moreover, customers are increasingly treating e-retail as interchangeable with other sales channels and retailers. As one interviewee said, e-commerce “should drop the



‘e’; it’s basically commerce now,” with customers willing to change to another retailer or sales channel if it can provide the item more quickly.

Another part of the strategic move towards regional e-fulfillment relates to the industry’s maturity and sales volume. When a retailer makes only a small fraction of its total sales through e-retail, it is possible to co-locate e-fulfillment and B&M logistics functions because e-fulfillment volume is not so large as to be unwieldy within the B&M distribution network. However, many retailers have found that e-retail growth makes it more practical to serve the sales channels from separate facilities. ‘Ship-from-store’ maintains e-fulfillment within the existing logistics network while shifting e-fulfillment pick and pack functions from DCs to stores, which are on average closer to customers. Ship-from-store can create problems rebalancing inventory and increase employee’s workloads. Therefore, many firms have instead opted for a third strategy, which separates e-fulfillment from B&M distribution in its own network with separate facilities and transportation.

Air transportation primarily serves overnight deliveries in centralized fulfillment networks. (Amazon’s Prime Air may be a notable exception). Many retailers that use air transport for overnight shipments are small e-retailers with fewer than four FCs to serve the national market. Regionally oriented FCs or ship-from-store can often make overnight deliveries by ground.

#### 6.5.1.1 Product Types

Interviewees emphasize that e-retailers value different regional traits for warehouses as a function of the products served in those warehouses. Generally, companies

with higher value-to-weight or time-sensitive products more frequently ship by air (Vega 2008; Leinbach and Bowen 2004), and the prospect of needing air transport influences their location choices. For instance, one interviewee says that “typically, the only reason you’re shipping is it is truly something urgent, or...because you missed the window for trucking, rail, ocean.” Another interviewee highlights that some goods move by air for security reasons because of its low theft and pilferage rates.

#### 6.5.1.2 Geographic Focus

Two interviewees refer to cyclical patterns in how heavily companies weigh the opposing constraints of transportation costs (lower when inventory is decentralized near customers) and inventory costs (lower when inventory is centralized). Accordingly, FCs’ geographic focus is extremely variable as a function of the configuration of e-fulfillment networks. Generally, retailers are discarding the national distribution paradigm and embracing regional distribution. Amazon’s offering of same-day delivery has impelled retailers to consider smaller geographic areas of responsibility for FCs. Strategy and geographic focus vary not just at the facility level, but also at the product level. Some products or brands at an FC might be distributed nationally, while others are distributed regionally.

#### 6.5.2 *Regional Factors*

Retail warehouse location choice involves tradeoffs among desired traits. The interviews are analyzed to confirm, nuance, or expand the theory-based traits examined through the shipper survey. Most regional traits are confirmed, and a few are added. The

following subsections describe regional traits affecting warehouse location choice reported in interviews.

#### 6.5.2.1 Risk of Natural Disaster

Risk of natural disasters is one of the traits reported in the interviews that the survey did not include. A region's risk of natural disasters has gained prominence in the last roughly 15 to 20 years in the location of warehouses of all types. There have also been several natural disasters that highlighted risks of natural disasters in particular regions, such as Hurricane Katrina in 2005.

#### 6.5.2.2 Proximity to Integrator Air Hubs

Large and small integrator air hubs are a major attractor for logistics activity. An industrial real estate researcher specified that, while airports have been a "huge factor in the last few years" for industrial real estate, integrator air hubs are especially important. All integrator air hubs attract warehouses, not just the largest hubs. Non-hub cargo airports also stimulate industrial real estate markets. FCs primarily using ground modes may still benefit from proximity to an integrator air hub because ground shipments also have later drop-off times for overnight deliveries. Outbound transportation may also cost less originating from integrator air hubs than from other regions. An integrator representative reports that the integrator partners with shippers (including e-retailers) to design their networks in ways that reduce costs to the shipper and the integrator. Cost reduction strategies include locating facilities near an integrator air hub and maximizing use of ground modes. Integrators' choice among air and ground modes are flexible as a function of delivery requirements. According to another air cargo expert, some shipments for which

customers have purchased air delivery may still be transported by ground modes if truck transportation still allows the integrator achieve the customer's delivery window. Truck transportation's clear advantage to integrators is in reducing their cost. Proximity to an integrator air hub maximizes mode choices and routing options.

#### 6.5.2.3 Proximity to Integrator Ground Hubs and Sortation Centers

E-retailers locate FCs in regions that permit them to deliver to the most customers by ground. Centrality in integrator and USPS networks matters greatly to e-retailers. Location near integrator ground hubs also decreases carriers' response time and item shipment time. Integrator and postal sortation center are numerous and widespread. Most large cargo airports host nearby integrator ground hubs whether or not they also host integrator air hubs.

#### 6.5.2.4 Labor Costs

Labor costs affect industrial location choice generally. One interviewee observes that labor cost and availability have been among the most important influences on industrial and FC location, second only to customer proximity. Another interviewee notes that warehousing has long been migrating away from the northern U.S. in search of lower labor costs. Interviewees do not discuss labor costs in relation to e-fulfillment.

#### 6.5.2.5 Land Costs

Interviewees do not discuss land costs in relation to e-fulfillment.

#### 6.5.2.6 Taxes

Warehouses gravitate to low-tax states and regions. Sales tax is charged uniformly in e-retail based on the customer's location, so sales tax charged at the FCs' location is less important than sales tax charged at the customers' location.

#### 6.5.2.7 Skilled Workforce

Several interviewees cite workforce availability as a factor in FC location. An industrial real estate researcher cited labor as the second most important factor affecting FC location, only after customer proximity. Similarly, an economic developer cites workforce as a concern of many logistics companies. Concerns about labor availability have been more pronounced in the regions where the logistics industry has thrived. Most interviewees do not address workforce skills.

#### 6.5.2.8 Business Friendly Regulation

No interviewees reference business-friendly regulation explicitly. However, several regions contain active efforts led by economic developers to communicate logistics industry needs to policymakers. These efforts imply a belief in the efficacy of proper laws and investments to facilitate logistics.

#### 6.5.2.9 Interstate Highway Proximity

Four of the interviewees emphasize that trucks deliver most e-retail orders, which implies the need for high-quality roads. As one interviewee relates, a warehouse can be modern and advanced, but "if it doesn't connect to a freeway, you're shit out of luck."

#### 6.5.2.10 Airport Proximity

The interviewees are divided on the importance of airport proximity to FC operations. Two interviewees emphasize that most e-retail shipments are transported by truck and that sites are therefore selected to maximize ground population access. Apparent correlation with airport location could come from unrelated factors correlated with airport location, such as labor market or customer centrality. Several other interviewees believe that proximity to airports can still affect FC location choice by providing a later cutoff time for the minority of shipments that are overnight deliveries and lowering transportation costs.

#### 6.5.2.11 Rail Proximity

None of the interviewees address rail proximity. Rail appears to be low-priority for most e-retail shipments.

#### 6.5.2.12 Seaport Proximity

Seaport proximity primarily matters for processing imports. Containerization and offshoring increased the number of warehouses near major import seaports. Seaports primarily attract warehouses processing imports rather than customer-oriented FCs.

#### 6.5.2.13 Proximity to Suppliers

None of the interviewees address supplier proximity.

#### 6.5.2.14 Proximity to Customers

Customer proximity is the largest influence on FC location according to many interviewees. Customer expectations for rapid delivery are making proximity to customers even more influential. According to some interviewees, customer proximity is so important that it belongs in its own category, particularly for last-mile FCs. Customer proximity is the primary factor motivating e-retailers to pursue regional (rather than national) e-fulfillment. Companies first select a region for the FC based on proximity to the consumer bases that the e-retailer wants to serve, and only then evaluate sites within the region based on labor access, building functionality, and access to the broader air and ground transportation networks. Evaluation of customer proximity precedes and underpins evaluation of other regional traits.

### 6.5.3 *Outbound Transportation*

#### 6.5.3.1 Modes

Trucks transport most domestic e-retail shipments from FCs to customers. An e-retailer representative interviewed reports 90% or greater of e-retail orders being transported by truck. Still, e-retailers transport a higher proportion of shipments by air than equivalent B&M retailers. The same FC that transports 90% of outbound e-fulfillment by truck also moves 98% - 99% of outbound shipments for B&M retail by truck. In this case, e-retail increases the retailers' air shipment volume by five to ten times. Conversely, international e-retail uses air transport extensively.

#### 6.5.3.2 Carriers

Interviewees agree that both integrators and USPS currently provide the majority of transportation services for most e-retailers, which aligns with survey results. These carriers employ both air and ground modes.

Several interviewees discussed the role of passenger airlines' bellyhold capacity in e-retail shipments. According to a passenger airline representative, the extensive regulations on bellyhold cargo often spur customers shipping hazardous goods to only consider a cargo airline. Another interviewee believes that passenger airlines may be able to capture many e-retail shipments, both on long-distance domestic and international routes. Passenger airlines ply medium- and long-distance routes more regularly and sometimes with fewer stops than freighters. Airports can manage "facilitation centers" that could register as known shippers, process hazardous goods, and transfer cargo to passenger airlines, thereby avoiding some of the most onerous regulations on passenger airlines.

### **6.6 Conclusions from the Shipper Surveys and Logistician Interviews**

The results support most alternative hypotheses. Airport proximity is much more important to FCs than to DCs, and proximity to integrator air hubs is especially valuable. Airport access is not e-retailers' most important regional trait, but it is still relatively important. Predictably, downstream logistics factors (i.e., those related to customer location and delivery) influence FC location less than upstream factors. FCs use air transport much more frequently than DCs, and FCs also regularly employ integrators and USPS. Nearly all FC respondents are in the same metropolitan region as an integrator air hub, and they enjoy later drop-off times for next-day shipments than DCs.



DCs are more concerned than FCs with cost factors, whether labor or land, and with access to trucks using Interstate Highways. Air transport barely registers in DC distribution. Airport proximity is the least important regional trait, and air transport is rarely used for outbound deliveries to stores. Instead, B&M distribution networks rely on TL and LTL shipment, generally to a regionally-defined set of stores.

The interviews with logistics professionals confirm and nuance most survey results. For example, location choice occurs within a context of a firm's overall logistics strategy. Those strategies are changing in ways that are reducing FCs' geographic area of responsibility and decentralizing inventory to achieve faster delivery. Competition with Amazon is making customer proximity ever more important for small e-retailers.

There are several limitations to the survey. Although the response rate of 5.8% is roughly aligned with similar surveys, it is low in absolute terms, which hinders statistical tests' ability to detect differences between the sales channels. Type II error ('false negatives') is doubtlessly widespread, preventing real differences from being recognized. The low response rate also raises the specter of selection bias. The most notable example of selection bias is Amazon, which makes up two thirds of the sampling frame but did not provide any survey responses. The omission of Amazon tilts the e-fulfillment sample towards smaller and newer firms compared with the B&M sample. This creates the possibility that differences attributed to sales channel may instead be due to maturity, size, and economies of scale. The risk of misattribution is mitigated by the alignment of responses between small e-retailers and large B&M retailers with small e-retail components.

## **CHAPTER 7. AIRPORT PLANNING BENCHMARKING**

### **7.1 Introduction**

Airport planning benchmarking has two sections. It begins with a document review of planning documents at ten airports whose size and traits suggest a moderate-to-large e-fulfillment presence. These document reviews display trends in airport staffs' perceptions of e-fulfillment and planning responses. The second section consists of interviews with officials at airports served by Amazon Prime Air, the only entirely e-retail air operation. The interviews reveal how airports with visible e-retail cargo think about its opportunities and planning challenges. The reviews and case studies are synthesized into a state of practice.

### **7.2 Document Review**

Table 17 describes the ratings assigned to airports across five analytical sections. A rating of 'no,' 'partial' or 'inconclusive' does not imply fault on the part of the airport plan. The planners may have correctly determined that there is inadequate benefit from the inclusion of e-fulfillment in the process based on their analysis of local conditions and airport priorities, which this dissertation seeks neither to replicate nor contradict.

**Table 17. Rating descriptions.**

<b>Category</b>	<b>No</b>	<b>Partial</b>	<b>Yes</b>
E-fulfillment influence	Cargo trends and influences not addressed.	Cargo trends and influences are addressed. They do not specifically relate to e-fulfillment.	E-fulfillment or equivalent terms explicitly mentioned as a cargo trend or influence.
Forecasting	Cargo not forecast or forecast with approach that does not account for cargo dynamics (e.g., extrapolation from passenger forecasts).	Cargo forecast with approach that considers cargo dynamics. More closely approximates e-fulfillment if integrators are forecast separately from general cargo.	E-fulfillment included either as factor affecting growth rates or through qualitative or quantitative consideration.
Freight community involvement	No freight community members involved.	Freight community members involved. E-fulfillment represents small fraction of their interests.	E-fulfillment representatives consulted, or freight community consulted about e-fulfillment.
Investments and policies	Does not use forecasts to estimate cargo infrastructure needs.	n/a	Uses forecasts to estimate cargo infrastructure needs.
Land development	Does not address land needs for airport-related logistics on or off airport property. Does not seek to spur logistics development.	Addresses land needs for airport-related logistics on or off airport property. E-fulfillment not specified.	Addresses land needs for airport-related e-fulfillment on or off airport property or refers to another document that does so.

**Note: ‘Inconclusive’ means that the rating cannot be deduced from the documentation alone.**

The results of the ten document reviews are detailed in the following subsections and are summarized in Table 18, Table 19, and Table 20. Several plans explicitly address e-fulfillment as an influence on demand for air transport, and many highlight integrators' needs, which implicitly acknowledges e-fulfillment because of e-fulfillment's heavy use of integrators. Planners frequently employ scenario-based forecasting approaches. Freight community involvement is often used to seek input from airport users. Moreover, planners at most airports involve cargo airlines in the planning process, which indirectly provides feedback from shippers, potentially including e-retailers. Planners at all airports forecast cargo activity to gauge the adequacy of airport cargo infrastructure and plan improvements. Planners at approximately half of the airports include real estate development plans for on-airport property or consider the airport's influence on surrounding properties.

**Table 18. Summary of document reviews (part 1).**

Airport code	<b>ATL</b>	<b>CAE</b>	<b>CLT</b>	<b>CVG</b>
City	Atlanta, GA	Columbia, SC	Charlotte, SC	Hebron, KY
Publication year	2014	Approx. 2011	2016	2013
Cargo ramp area (m <sup>2</sup> )	150,272	90,196	60,428	181,590
Annual cargo tonnage (2016)	626,202	29,922	135,086	729,309
Cargo hub / Passenger hub	none / Delta Air Lines & Southwest	UPS / none	none / American Airlines	DHL & Amazon Air / none
E-fulfillment influence	<b>No.</b> Does not address influences on cargo	<b>Partial.</b> Implicit through focus on integrators	<b>Yes.</b> E-commerce one of four trends driving air cargo	<b>Partial.</b> Implicit through focus on integrators
Forecasting	<b>No.</b> Scenarios based on growth rates from Boeing, FAA, and historical trends	<b>No.</b> Growth rates based on FAA Aerospace Forecasts	<b>Partial.</b> Growth rates from Boeing, which likely include national e-fulfillment trends	<b>Partial.</b> Scenarios that account for DHL growth and DHL withdrawal
Freight community involvement	<b>Inconclusive.</b> Freight community involvement in scoping sessions included Delta, Southwest, ARC, and nearby cities	<b>Inconclusive.</b> Interviews with the freight community, but probably not members representing e-fulfillment	<b>No.</b> Freight community members not consulted	<b>Partial.</b> Heavy involvement of DHL via interviews strategy analysis. DHL, FedEx, and passenger airlines in technical advisory committee
Investments and policies	<b>Yes.</b> Analysis of future space requirements and current space	<b>Yes.</b> Analysis of cargo needs and space	<b>No.</b> Models details of passenger movement and needs, but not cargo	<b>Yes.</b> Analysis of cargo needs and space
Land development	<b>Yes.</b> E-fulfillment addressed in related Aerotropolis Atlanta Blueprint	<b>Partial.</b> Real estate development on airport-owned property for logistics	<b>Yes.</b> Detailed real estate plan including e-fulfillment in Airport Commercial Development Strategy	<b>Partial.</b> Acknowledges OKI Freight Plan's recommendation of "Air Cargo Park" at CVG. Addresses potential on-airport land uses

**Table 19. Summary of document reviews (part 2).**

Airport code	<b>DFW</b>	<b>GSO</b>	<b>JFK</b>	<b>LCK</b>
City	Dallas-Ft Worth, TX	Greensboro, NC	New York, NY	Columbus, OH
Publication year	2009	2010	2012	2017
Cargo ramp area (m <sup>2</sup> )	225,232	68,623	211,443	91,677
Annual cargo tonnage (2016)	670,029	68,991	1,286,484	91,682
Cargo hub / Passenger hub	UPS & Ameriflight / American Airlines	FedEx / none	Atlas Air, Kalitta Air, Polar Air Cargo / American Airlines, Delta Airlines & JetBlue Airways	AirNet Express
E-fulfillment influence	<b>Partial.</b> Implicit through surrounding logistics development	<b>Yes.</b> E-fulfillment explicitly addressed as trend	<b>Yes.</b> E-fulfillment explicitly addressed as trend	<b>Yes.</b> E-fulfillment explicitly addressed as trend
Forecasting	<b>Partial.</b> Scenarios based on Airbus and Boeing global forecasted growth rates, and integrator hub choices	<b>Inconclusive.</b> Origin of FedEx growth rates unclear	<b>Partial.</b> Scenarios reconciled with both trend and econometric forecasts	<b>Yes.</b> Quantitatively estimates e-fulfillment's potential freight contribution by analyzing businesses' activity
Freight community involvement	<b>Inconclusive.</b> Unspecified freight community members helped craft planning goals	<b>Inconclusive.</b> No e-fulfillment representatives, but FedEx may have conveyed e-fulfillment interests	<b>Inconclusive,</b> but likely. Conducted interviews with shippers, carriers, and tenants	<b>Partial.</b> Interviews with "freight stakeholders and cargo owners"
Investments and policies	<b>Yes.</b> Compares integrator space needs with forecasts, and proposes alternatives	<b>Yes.</b> Seeks to preserve land for cargo growth	<b>Yes.</b> Proactive policies to strengthen air cargo institution in Port Authority, ease truck access, attract new airport users	<b>Yes.</b> Final recommendations in process
Land development	<b>Partial.</b> Land use plan includes industrial land	<b>Yes.</b> Seeks to use airport to attract logistics and e-fulfillment	<b>Partial.</b> Very extensive planning for off-airport cargo village, which likely implies e-fulfillment	<b>Yes.</b> Land development extensively addressed through Rickenbacker Global Logistics Park

**Table 20. Summary of document reviews (part 3).**

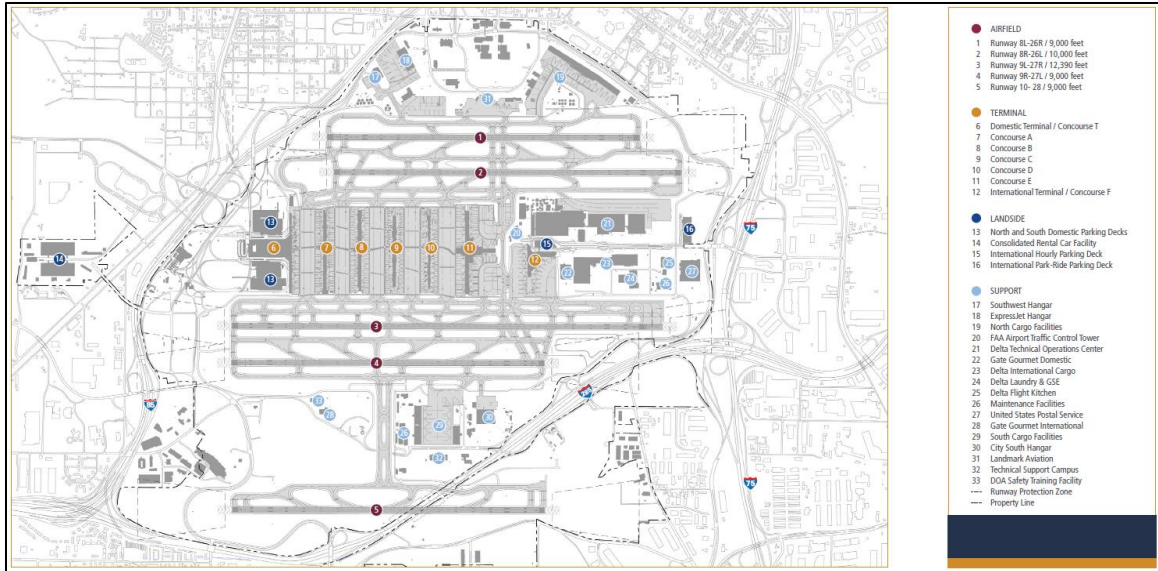
Airport code	<b>MSP</b>	<b>PHX</b>
City	Minneapolis-St. Paul, MN	Phoenix, AZ
Publication year	2010	2014
Cargo ramp area (m <sup>2</sup> )	130,808	122,229
Annual cargo tonnage (2016)	199,340	283,465
Cargo hub / Passenger hub	none / Delta Air Lines & Sun Country Airlines	Ameriflight / American Airlines & Southwest Airlines
E-fulfillment influence	<b>No.</b> E-fulfillment and freight mostly omitted	<b>Yes.</b> E-fulfillment explicitly addressed as trend
Forecasting	<b>No.</b> Does not consider freight trends. Bases cargo forecasts on passenger volume	<b>Yes.</b> Qualitatively accounts for e-fulfillment through interviews with growth estimates from freight community
Freight community involvement	<b>Inconclusive,</b> but unlikely. Did not include freight representatives	<b>Yes.</b> Includes e-fulfillment and freight community representatives
Investments and policies	<b>No.</b> Does not consider freight infrastructure	<b>Yes.</b> Analysis of cargo needs and space
Land development	<b>No.</b>	<b>No.</b>

### *7.2.1 Hartsfield-Jackson Atlanta International Airport (ATL)*

Hartsfield-Jackson Atlanta International Airport (ATL) is primarily known for its passenger traffic derived from Delta Air Line's long-time hub and a secondary focus city by Southwest Airlines. Although it hosts flights from several cargo airlines, has moderate integrator activity, and has considerable bellyhold capacity, its cargo ranking is much lower than its passenger ranking. ATL processes only 15% as much cargo weight as Memphis International Airport (MEM), the country's busiest cargo airport (Airports Council International - North America 2015).

The airport has five parallel runways and three passenger terminals (North, South, International) on either end of seven midfield concourses. Cargo facilities are situated in three main areas. The North Cargo Facility serves UPS and FedEx, and it is located on the airport's north side. Midfield next to the International Terminal is Delta Air Lines' international cargo terminal. Finally, the South Cargo Terminal is located directly north of the southernmost runway (10/28), and it serves freighters from airlines such as Cathay Pacific, China Airlines, and Korean Air. Figure 34 depicts the runways, passenger terminals, and cargo terminals.





**Figure 34. ATL airport map.**

**Source: ATL master plan, executive summary, p. 6**

The airport and the airport region are well positioned for cargo growth. The airport is adjacent to logistics clusters found near the intersection of several Interstate Highways on the south side of Atlanta. Recently the zone has attracted several e-retailers and many warehouses. The concentration of logistics activity has drawn the attention of cities and regional organizations, which are promoting airport-oriented economic development in several industries including logistics. The City of College Park's property marketing website<sup>3</sup> shows aerial images that highlight each parcel's proximity to the airport. Several organizations including surrounding counties, chambers of commerce, economic development organizations, and major local companies formed the Aerotropolis Atlanta Alliance in 2014, whose blueprint for the region addresses land development leveraging the airport's connectivity (Aerotropolis Atlanta 2016). Implementation partially rests with

<sup>3</sup> [www.360collegepark.com](http://www.360collegepark.com)

the Aerotropolis Atlanta Community Improvement District (CID), which includes portions of land adjacent to and west of the airport (Aerotropolis Atlanta Community Improvement District 2017). The region has also attracted developers' attention, with the Gillem Logistics Center as just one example that explicitly seeks to benefit from the highway and airport connections (Forest Park Development Partners 2017).

ATL is operating under a master plan published in March 2015, which updates the previous plan from 1999. The airport had experienced numerous changes since the 1999 plan, including the enhanced security procedures that followed the September 11<sup>th</sup> attacks, the acquisition of one of its largest airlines (AirTran) by Southwest Airlines, and a move by Delta Air Lines away from the smallest regional jets (ATL master plan, Executive Summary, p. 2). The plan has five steps including inventory, aviation activity forecast, facility requirements, alternatives development, and development planning.

**ATL master plan:** City of Atlanta. 2015. "Hartsfield-Jackson Atlanta International Airport Master Plan Executive Summary."

#### 7.2.1.1 E-fulfillment Influence

The master plan does not explicitly or implicitly address e-fulfillment. The master plan does not have cargo-specific goals (ATL master plan, 5-2), and it does not explicitly address influences on cargo behavior. The closest that the plan comes to implicitly addressing e-fulfillment is in acknowledging practices such as just-in-time manufacturing that encourage the use of air transport.

#### 7.2.1.2 Forecasting

Forecasting does not consider e-fulfillment even though the plan uses a scenario approach that is adaptable to e-fulfillment. Domestic and international cargo activity are projected based on macro-scale forecasts by Boeing, Airbus, and the FAA. The planners combine institutional forecasts with an understanding of economic conditions to select growth rates for domestic and international cargo for each scenario (ATL master plan, 3-48). The planners attribute identical growth rates to dedicated freighter cargo and integrator cargo, while linking bellyhold cargo activity with separate forecasts of passenger aircraft movements. Integrators' percentage of air cargo weight is set at a constant 43% (ATL master plan, 3-50). The fact that integrator and freighter cargo rates are identical signifies that e-fulfillment is not explicitly considered in growth rates because domestic e-fulfillment leans heavily towards integrators and mail.

#### 7.2.1.3 Freight Community Involvement

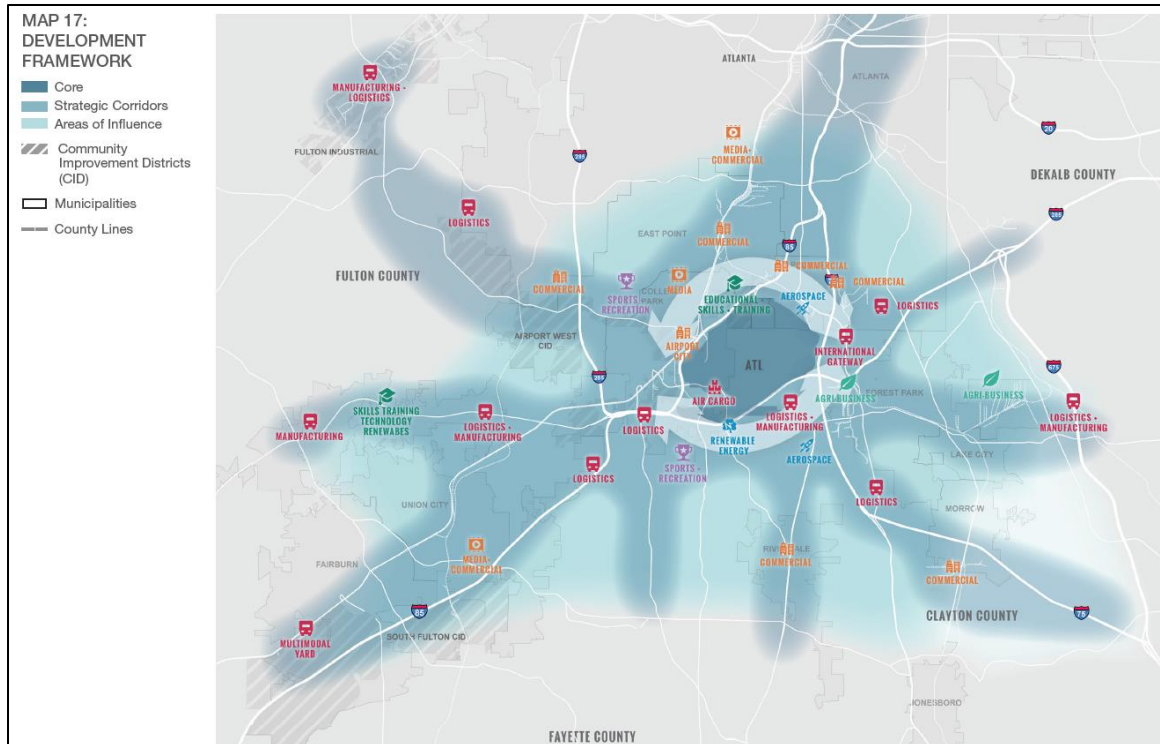
Stakeholder involvement does not appear to include the e-retail shippers or integrators, even though freight representatives from airlines or regional organizations could have conveyed e-retailers' interests. Industry representation from Delta Air Lines and Southwest Airlines informed the plan. Planners also consulted with the area MPO, the Atlanta Regional Commission (ARC), whose freight staff also could have conveyed freight needs to airport planners (Atlanta master plan, 1-5).

#### 7.2.1.4 Investments and Policies

Planners compare cargo demand forecasts with capacity to assess the airport's infrastructure needs. They transform cargo activity into infrastructure requirements using conversion rates. They also identify differences between requirements and existing infrastructure. Landside cargo roadways is not considered.

#### 7.2.1.5 Land Development

The plan does not address off-airport land development. Nonetheless, the related Atlanta Aerotropolis Blueprint envisions airport-centric development with large logistics clusters that could include e-commerce, as picture in Figure 35 below (Atlanta Regional Commission and Aerotropolis Atlanta Alliance 2016).



**Figure 35. Atlanta aerotropolis development framework.**

**Source: Atlanta Regional Commission and Aerotropolis Atlanta Alliance (2016).**

#### 7.2.1.6 Conclusion

The ATL master plan focuses on its largest activity segment, which is passengers. E-fulfillment is being linked with the airport through initiatives like the Atlanta Aerotropolis Alliance that supplement the airport planning process.

#### 7.2.2 *Columbia Metropolitan Airport (CAE)*

The Columbia Metropolitan Airport (CAE) is the country's 115<sup>th</sup> busiest passenger airport with approximately half a million annually emplaned passengers, and it is the 56<sup>th</sup> busiest cargo airport with half a billion pounds of landed weight in 2016 (Federal Aviation Administration 2016). It hosts a UPS hub that opened in 1994 and is capable of handling

42,000 packages per hour (CAE master plan, 10-10). According to FlightAware,<sup>4</sup> CAE hosts FedEx flights to Memphis, TN (MEM) and Indianapolis, IN (IND), as well as UPS flights to Dallas, TX (DFW) and Oakland, CA (OAK) among others. As of plan completion (estimated 2011), common freight destinations included Philadelphia, PA (PHL); Louisville, KY (SDF); Flint, MI (FNT); Memphis, TN (MEM); Myrtle Beach, SC (MYR); Savannah, GA (SAV), and Wilmington, OH (ILN) (CAE master plan).

The airport has two intersecting runways, with passenger and general aviation facilities on its north side. Cargo terminals are divided between the UPS terminal on its eastern side and a terminal for FedEx and other airlines to the northwest (center right and upper left of Figure 36 respectively). The UPS terminal spans Edmund Highway, with airside activities located on its western side and landside activities on its eastern side.

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<sup>4</sup> <https://flightaware.com/>



**Figure 36. CAE airport map.**

**Source: CAE master plan, 1-3.**

Columbia, SC is the capital of South Carolina, and home of Fort Jackson and the University of South Carolina. The region houses approximately 800 thousand people (U.S. Census Bureau 2017a). Population grew 6% between 2010 and 2016. It is the country’s 71<sup>st</sup> largest metropolitan region by economic size, with annual economic activity of \$38 billion (Bureau of Economic Analysis 2016).

The Richland Lexington Airport District (RLAD) manages the airport. The original master plan dates from 2003, but the version being analyzed was completed in or shortly after 2011. The Columbia Metropolitan Airport Master Plan (hereafter called the “CAE master plan”) states that its primary focus is on “short and intermediate-term actions to improve air transport access, passenger terminal efficiency and security, air safety, and to

maximize development and economic impact to generate resources to support CAE” (CAE master plan, 1-1).

**CAE master plan:** Richland-Lexington Airport District. 2010. “Columbia Metropolitan Airport Master Plan Update.”

#### 7.2.2.1 E-fulfillment Influence

The planners demonstrate consciousness of e-fulfillment in the region and its effect on air cargo. For instance, they cite Amazon’s FC in nearby Cayce that opened in 2011, indicating that they implicitly recognize the link between e-retail and air cargo by discussing the Amazon FC in the same paragraph as UPS’s hub (Richland-Lexington Airport District 2010) (CAE master plan, 10-10).

#### 7.2.2.2 Forecasting

Planners account for the cargo generation factors cited in FAA Advisory Circular (AC) 150/5070-6 (titled *Airport Master Plans*)<sup>5</sup> (Richland-Lexington Airport District 2010) (CAE master plan, 3-1). They also recognize the challenges of long-term forecasting, since unforeseeable events can arise (Richland-Lexington Airport District 2010) (CAE master plan, 3-2). Planners create a composite passenger forecast based on market share analysis, regression between population and operations, and trend extrapolation.

CAE accommodates substantial cargo activity, with an average of 20 aircraft daily (7,452 per year). Planners examine the major carriers’ flights and aircraft (CAE master

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<sup>5</sup>[https://www.faa.gov/documentLibrary/media/Advisory\\_Circular/150-5070-6B-Change-2-Consolidated.pdf](https://www.faa.gov/documentLibrary/media/Advisory_Circular/150-5070-6B-Change-2-Consolidated.pdf)



plan, 3-32), and FAA-identified trends (CAE master plan, 3-33). Cargo is forecast based on FAA growth rates (CAE master plan, 3-33) provided by the FAA Aerospace Forecasts 2009-2025.<sup>6</sup> The FAA Aerospace Forecasts account for dynamics affecting aviation like fuel prices, economic growth, security regulations, and structural changes. Applying the FAA's nationwide forecasts locally produces reasonable estimates that nonetheless do not account for local conditions. Moreover, even recent versions of the FAA Aerospace Forecasts do not explicitly reference changes in cargo generation caused by e-fulfillment.

#### 7.2.2.3 Freight Community Involvement

Planners do not appear to have consulted e-fulfillment freight community members, although this assessment cannot be conclusively accepted based on the master plan. For example, planners interviewed unidentified stakeholders to gather data (CAE master plan, 2-1) and presented development options to stakeholders (CAE master plan, 1-10).

#### 7.2.2.4 Investments and Policies

Planners compare existing infrastructure to forecasted needs and propose corresponding airside infrastructure. For example, the aircraft serving Columbia that requires the longest runway length is a specific variant of the 767-300, which requires longer runways for than current available a fully loaded takeoff (CAE master plan, 5-9). The CAE master plan recommends “a 2,399-foot extension to the end of Runway 11 in order to achieve an ultimate length of 11,000 foot,” as required for this aircraft variant (CAE master plan, 5-10). Most 767s serving CAE carry cargo rather than passengers,

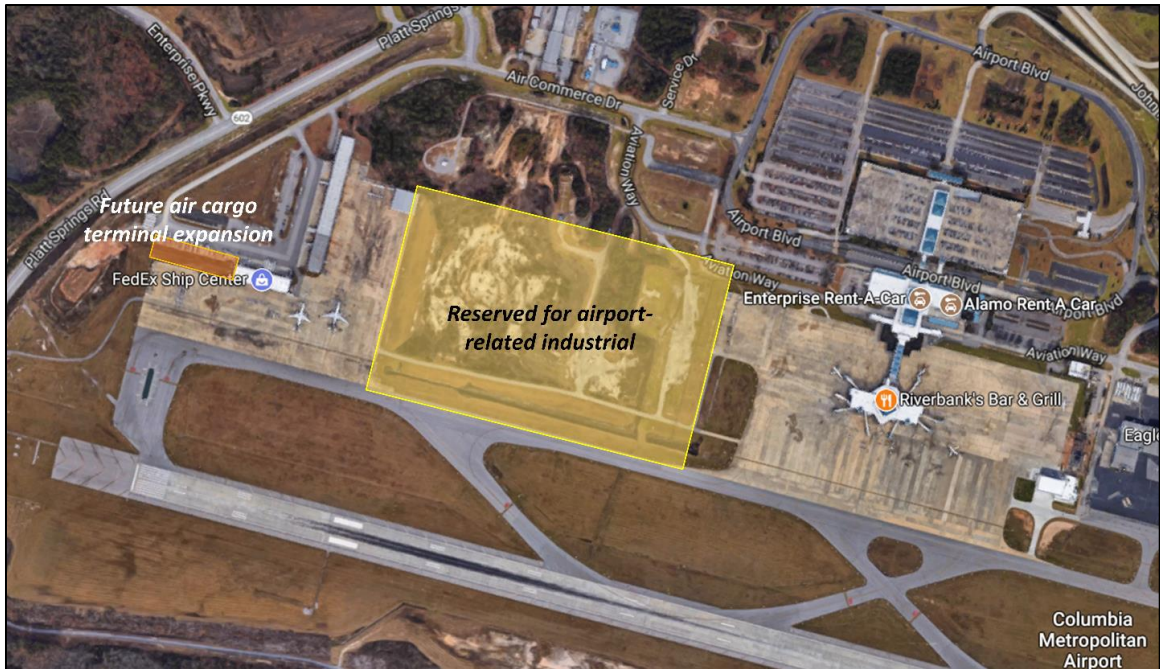
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<sup>6</sup> [https://www.faa.gov/data\\_research/aviation/aerospace\\_forecasts/2009-2025/media/2009 Forecast Doc.pdf](https://www.faa.gov/data_research/aviation/aerospace_forecasts/2009-2025/media/2009_Forecast_Doc.pdf)

signifying that the runway extension supports cargo. The CAE master plan also compares the area of the cargo apron with forecasted cargo aircraft operations to assess adequacy (CAE master plan, 5-32).

#### 7.2.2.5 Land Development

The CAE master plan extensively addresses the development potential of airport-owned land, including for logistics. The airport district owns multiple properties adjacent to the main body of the airport (CAE master plan, 5-33), some of which it is preserving for aeronautical uses or buffers, and some of which it has already sold for aviation-related uses. There is also a large plot directly adjacent to the cargo terminal and taxiways that it is preserving for aviation-related industrial uses (CAE master plan, 6-21) (Figure 37).

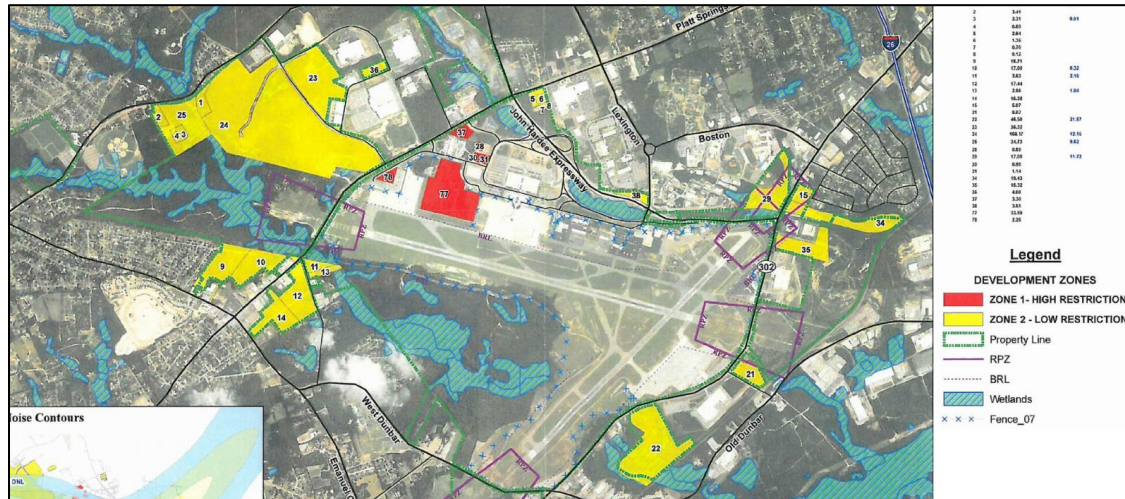


**Figure 37. Land reserved for airport-related industrial uses at CAE.**

**Source: Diagram created by author with aerial imagery from Google Maps.**

The CAE master plan includes a chapter on real estate development (“Chapter 10: Conceptual Real Estate Development Plan”), in which the planners analyze “airport-owned land that should be considered for non-aviation development” (CAE master plan, 10-1). The land is analyzed based on aeronautical restrictions, access, area, and topography (aeronautical restrictions are depicted in Figure 38). Land is deemed to have commercial viability, industrial viability, or no development potential as a function of market needs, and aeronautical and environmental restrictions (CAE master plan, 10-5). The airport commission has already developed some of the land beyond the northwest cargo terminal into the Columbia Metropolitan Airport Industrial Park, with some parcels serving as warehousing and distribution. Another large land parcel southwest of runway 11/29 (near

Emmanuel Church Road and Platt Springs Highway) is designated for commercial uses because of its proximity to residences.



**Figure 38. CAE airport-owned land categorized by aeronautical restrictions.**

**Source: CAE master plan.**

#### 7.2.2.6 Conclusion

Planners consider the development potential of airport-owned properties near cargo terminals, including for logistics. Several sections require additional information to understand if planners account for e-fulfillment.

#### 7.2.3 *Charlotte Douglas International Airport (CLT)*

Charlotte Douglas International Airport (CLT) is the ninth busiest passenger airport in the country with 45 million passengers in 2015, and it is the 32<sup>nd</sup> busiest cargo airport, with 135 thousand metric tons of cargo (Airports Council International - North America 2015). CLT processes 3% as much cargo weight as Memphis International Airport (MEM). The airport is the second largest hub in American Airlines' network since its 2015 merger

with US Airways. Cargo carriers such as UPS, FedEx, and Ameriflight each operate flights to several destinations. Additionally, Air Transport International (ATI), which serves Amazon Prime Air, has begun operating flights between CLT and Cincinnati (CVG), while Prime Air carrier Atlas Air also operate routes with Lehigh Valley International Airport (ABE) and Ontario International Airport (ONT).<sup>7</sup> CLT's air cargo tonnage peaked in 2006, declined by 32%, and recovered in the most recent years, growing 15% between 2015 and 2016 (Airports Council International - North America 2015). Dedicated freighters carry most cargo, with only 40% of cargo moving in bellyhold (CLT master plan, p. 2-27).

The Charlotte-Concord, NC-SC Combined Statistical Area (CSA) has two and a half million residents, which is roughly 1% of the national population (U.S. Census Bureau 2015). The region is also home to \$152 billion in GRP (Bureau of Economic Analysis 2016). In 2015, the Charlotte region's fastest growing industries were professional and business services, trade, education, and healthcare, while transportation lagged. The Charlotte region's economy grew over 4% in 2015, placing it among the top 15% of U.S. regions by year-over-year economic growth rate (Bureau of Economic Analysis 2016).

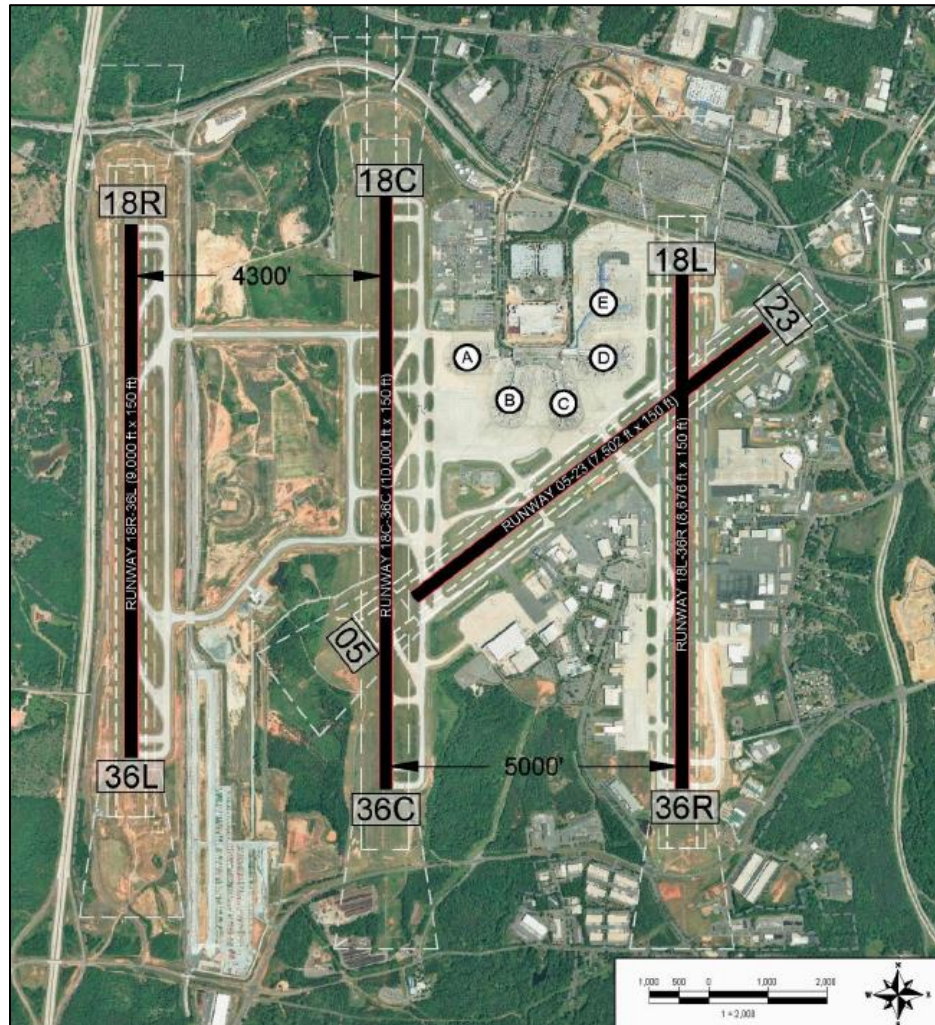
CLT airport has three parallel north-south runways, and one angled runway (05/23). It has a single mid-field passenger terminal with five concourses, most of which are dedicated to American Airlines and partners. Cargo terminals are located on the south side of the airport, directly opposite runway 05/23 of the passenger terminals, as well as on the western side of runway 18L/36R. Separate cargo terminals serve UPS, FedEx, American Airlines, and most other carriers. The airport also includes a unique facility: a Norfolk

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<sup>7</sup> Verified by checking flight records from CLT on FlightAware (<https://flightaware.com>).



Southern rail intermodal yard on airport property between runways 18C/36C and 18R/36L  
(Norfolk Southern 2017).



**Figure 39. CLT airfield map.**

**Source: CLT master plan, p. 3-2.**

CLT airport's *Master Plan Update: Airport Capacity Enhancement Plan* was released in 2016 (hereafter called the "CLT master plan"). The CLT master plan was undertaken to respond to the airport's steady passenger growth as an American Airlines hub, which has continued unabated since the merger. The last update was conducted in 2010. This update aims to meet growth needs through 2033 with airside and landside infrastructure. It was supplemented in 2017 by the Airport Commercial Development Strategy, which seeks to anchor growth in related industries around the airport (MXD Development Strategists et al. 2017). This section analyzes both plans.

**CLT master plan:** Landrum & Brown. 2016. "Charlotte Douglas International

Airport. Master Plan Update: Phase 1. Airport Capacity Enhancement Plan."

Charlotte Douglas International Airport.

<http://www.cltairport.com/News/Pages/DestinationCLTProjects.aspx>.

**CLT commercial development strategy:** MXD Development Strategists,

Jacobs, Kimley-Horn, and Lyerly Agency. 2017. "Charlotte Douglas

International Airport: Airport Commercial Development Strategy."

<http://www.cltairport.com/AboutCLT/Documents/Economic>

Development/CLT Airport Commercial Development Strategy FINAL March 27 2017.pdf.

#### 7.2.3.1 E-fulfillment Influence

Planners explicitly recognize e-fulfillment as an influence on air cargo. The air cargo forecast section begins by listing the factors that influence air cargo, which include e-retail / e-commerce, as well as truck substitution for air cargo, the trend of locating

manufacturing facilities near airports, and aircrafts' technological advancement in fuel efficiency, range, and payload. Regarding e-commerce, planners state that several types of retail are raising air cargo volumes, and that electronic repair (for example, of phones and computers) is having an especially large effect. These trends have primarily increased integrators' volumes, and secondarily expanded demand for bellyhold capacity (CLT master plan, p. 2-45).

#### 7.2.3.2 Forecasting

The forecasting approach partially accounts for e-retail cargo by employing spatially aggregate growth rates that consider e-fulfillment growth. Planners do not attune growth rates to local factors. Cargo activity is decomposed into three types for forecasting: domestic freight, international freight, and mail. Domestic cargo's growth rates mirror Boeing's air cargo activity forecasts for North America, while international cargo growth tracks Boeing's Latin American air cargo activity forecasts (since most of CLT's international cargo trade is with Latin America). Mail is forecast to grow at the same rate as domestic cargo (CLT master plan, p. 2-47). The approach of borrowing growth rates from spatially aggregate forecasts only accounts for trends like e-fulfillment to the extent that they were included in Boeing's forecasts. Boeing's latest forecast documentation does not detail its methodology, but it does list e-commerce as a factor (Boeing 2016).

The cargo volumes are converted to air carrier type and cargo hold type (i.e., bellyhold and dedicated freighter) by extending current splits among these carrier types. Cargo forecast to be transported by dedicated freighters is converted into aircraft



movements assuming future composition of aircraft fleets that are similar to the present (CLT master plan, p. 2-59). E-fulfillment could thwart these assumptions.

#### 7.2.3.3 Freight Community Involvement

The CLT master plan does not document freight community involvement. The plan documents consultation with passenger airlines about passenger terminal alternatives and repeated consultation with a Direction, Oversight, Review, and Agreement (DORA) work group composed of the FAA, CLT airport, American Airlines, and consultants (CLT master plan, p. 1-4).

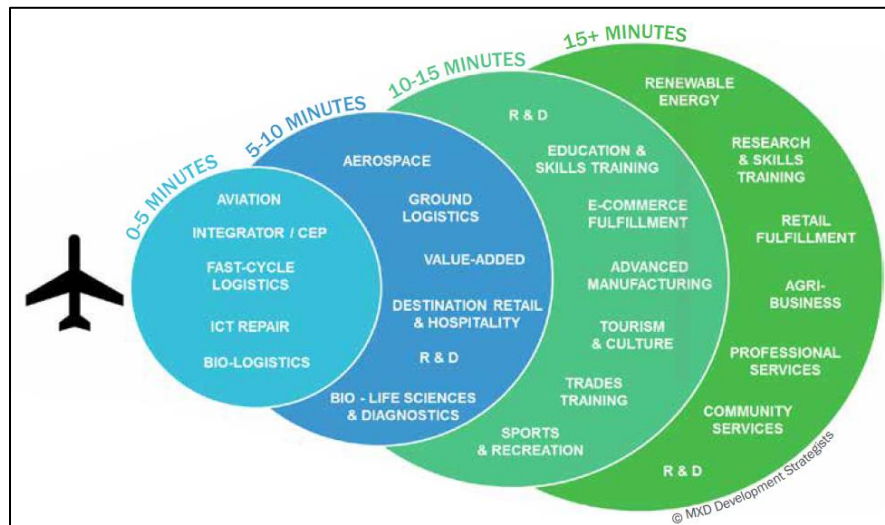
#### 7.2.3.4 Investments and Policies

Planners model many aspects of airport activity to ensure that current and proposed runways, taxiways, gates, and passenger areas are sufficient to accommodate the forecasted aircraft movements and passenger activity. The recommended terminal plan will require the demolition of many existing cargo facilities (CLT master plan, p. 8-23). Planners do not compare cargo needs with existing facilities or seek to adjust policies to accommodate cargo.

#### 7.2.3.5 Land Development

Land development recommendations are provided in the Airport Commercial Development Strategy, that the City of Charlotte commissioned to encourage private-sector development around the airport (MXD Development Strategists et al. 2017). Consultants performed a market analysis to identify compatible, self-sustaining industries that would provide non-aeronautical revenue to the airport. Logistics is a major component

of suitable activity, with fast-turn logistics close to the airport and “e-commerce fulfillment” targeted to be 10-15 minutes from the airport. Figure 40 displays the targeted industries by time distance.

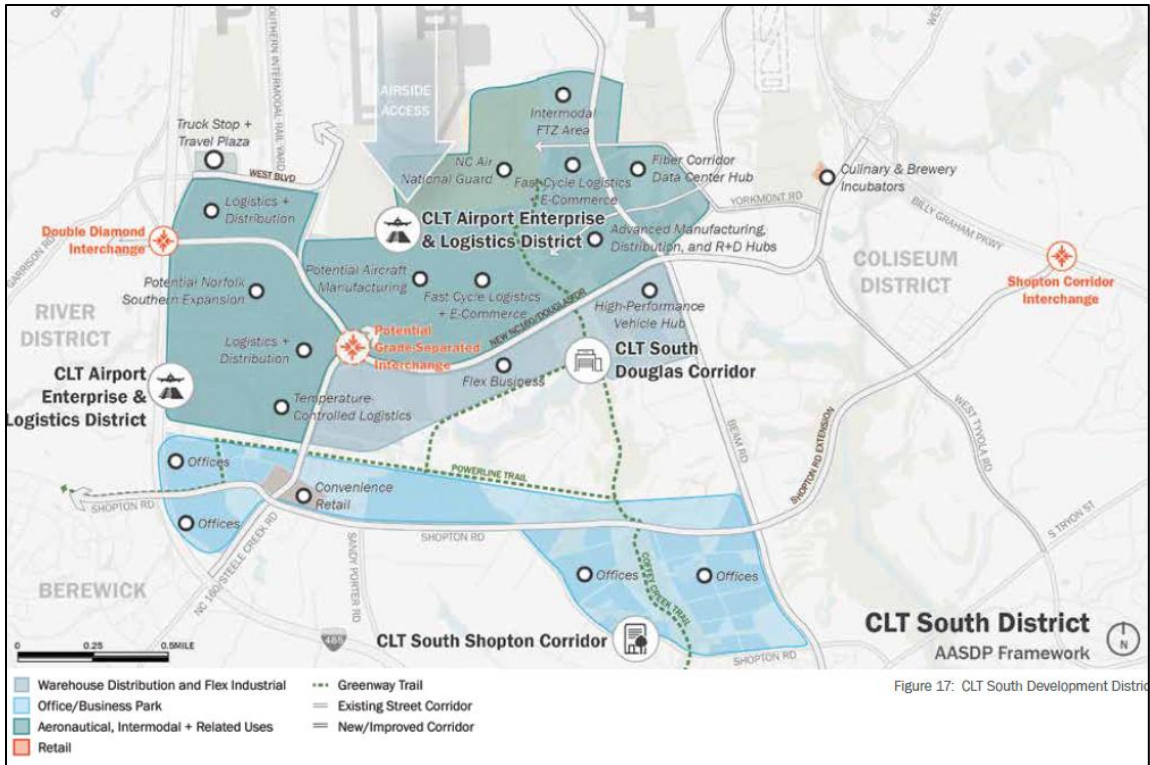


**Figure 40. CLT airport’s targeted industries by time distance.**

**Source: MXD Development Strategists (2017).**

**Note: Low image quality in original.**

The Airport Commercial Development Strategy proposes a freight- and logistics-focused district south of the airport, near the present-day cargo terminals and the Norfolk Southern intermodal terminal. The district is expected to accommodate e-fulfillment, as shown in Figure 41. Actions to promote logistics development in the region are specified, including construction of a temperature-controlled warehouse, roadway enhancements, truck fueling station, and incorporation of a foreign trade zone (MXD Development Strategists et al. 2017).



**Figure 41. Freight and logistics district south of CLT airport.**

**Source: MXD Development Strategists (2017).**

**Note: Low image quality in original.**

#### 7.2.3.6 Conclusions

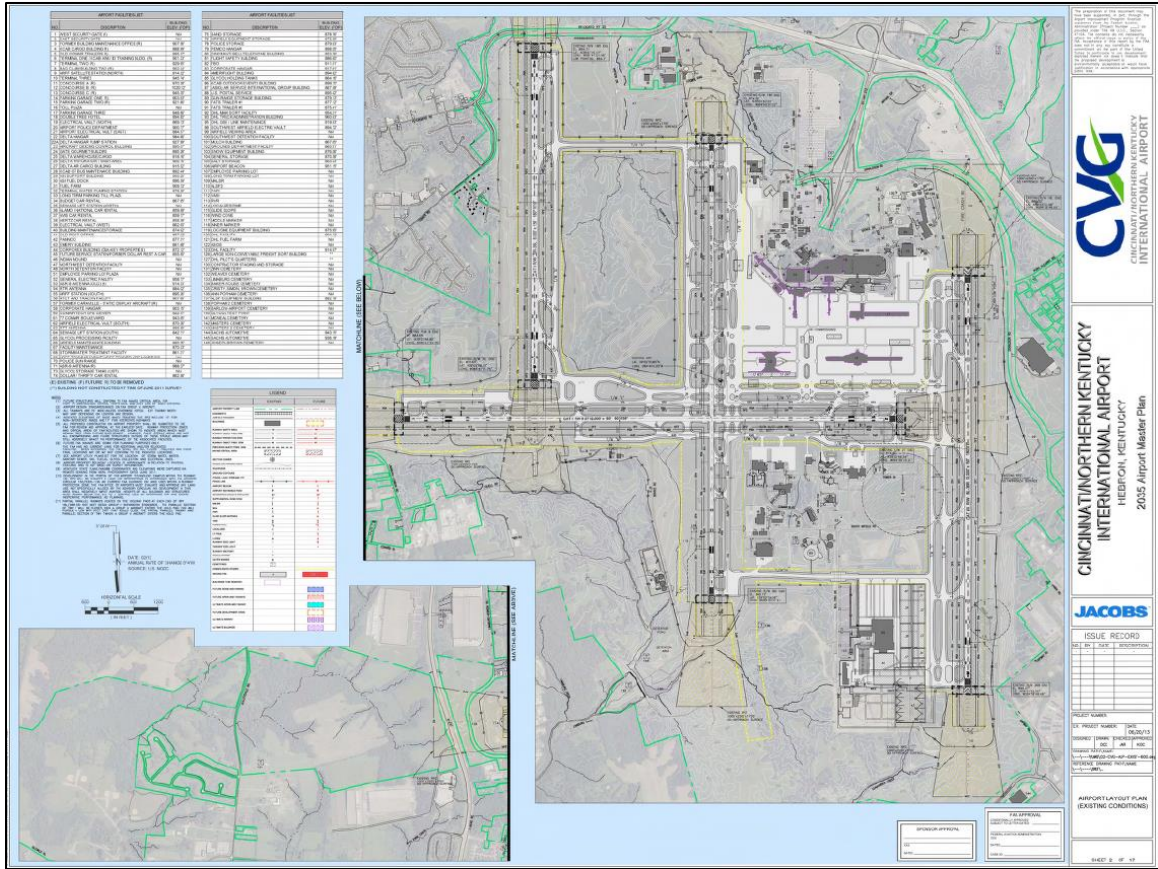
Planners address e-fulfillment at the beginning of the plan as an influence on air cargo, and they address e-fulfillment in the follow-up Airport Commercial Development Plan. In between, the CLT master plan's focus is on passenger travel.

#### 7.2.4 *Cincinnati/Northern Kentucky International Airport (CVG)*

The Cincinnati/Northern Kentucky International Airport (CVG) has experienced enough unforeseeable changes in recent decades to confound any airport plan. On the

Passenger activity boomed in the 1990s as Delta Air Lines and Comair together built a major hub, only to see the hub scaled back following passenger shrinkages after the attacks of September 11<sup>th</sup> and a prolonged Comair pilots' strike the same year. Comair ceased operations in 2012, and Delta shrank the hub to a shadow of its former self (CVG master plan, ES-5). On the cargo side, DHL maintained a hub in CVG, but after buying Airborne Express in 2003 it moved the hub to its proprietary airport in Wilmington, OH (ILN). The DHL hub returned to CVG in 2009 with only international flights (CVG master plan, 3-61). In early 2017, Amazon announced plans to build a Prime Air hub at CVG that will ultimately employ 2,700 people and utilize an estimated 40 aircraft (Wetterich and Caproni 2017). In 2015, the airport moved 729 thousand tons of cargo, which made it the ninth busiest in the country and represented 11.5% growth over the previous year (Airports Council International - North America 2015).

CVG airport has three parallel north-south runways, and one east-west runway. The passenger terminals are located midfield, and cargo terminals are on the north, center, and south sides of the airport. The largest terminal complex by far is the DHL facility located in the airport's southeastern corner (lower right of Figure 42). On the airport's northeast side is the Delta Air Lines cargo terminal, and another cargo terminal serving multiple airlines is just west of passenger terminal 1. Amazon has committed to building a very large cargo terminal between the center and westernmost runways (runways 18C/36C and 18R/36L respectively) (Wetterich and Caproni 2017).



**Figure 42. CVG airport map.**

**Source: CVG master plan, 7-11.**

The region has enjoyed mostly uninterrupted population growth since at least the 1950s, and is home to over 2 million people in 2016 (U.S. Census Bureau 2017a). Its GRP in 2015 was \$127 billion, which is nearly 1% of GDP (Bureau of Economic Analysis 2016). The region also hosts one of the largest e-fulfillment clusters in the country.

The Cincinnati/Northern Kentucky International Airport 2035 Master Plan Update (hereafter called the “CVG master plan”) was conducted in 2013, updating the 2007 plan. In addition to conducting an inventory of facilities, forecasting aviation activity, and

recommending capital projects, planners also evaluate facilities' maintenance expenses (CVG master plan, ES-3).

**CVG master plan:** Kenton County Airport Board. 2013. "CVG 2035 Master Plan."

#### 7.2.4.1 E-fulfillment Influence

The CVG master plan does not explicitly mention e-fulfillment as an influence on air cargo activity. Its focus on integrators' needs and strategy may implicitly include e-fulfillment, particularly in later chapters such as forecasting.

#### 7.2.4.2 Forecasting

Planners create two scenarios: one for DHL growth and another for DHL withdrawal. (The planning process precedes Amazon's announcement of an air hub). The forecasts revolve around DHL because the airline accounted for 95% of the airport's cargo volume at the time of planning (CVG master plan, 3-61). The scenarios were based on interviews with DHL employees and on historical data. Although DHL's hub serves international traffic, the forecasts' concentration on an integrator's strategy could implicitly account for growth related to e-fulfillment.

#### 7.2.4.3 Freight Community Involvement

Planners consulted with a technical advisory committee that includes staff from DHL, FedEx, and passenger airlines (CVG master plan, D-2). Interviews with DHL management informed the forecasts by providing planners with information about DHL's

plausible growth scenarios and constraints to growth. Although the CVG master plan does not specify the factors that DHL management referenced, they may have included e-fulfillment since it is heavily concentrated in the region (CVG master plan, 3-2).

#### 7.2.4.4 Investments and Policies

Air cargo needs are compared with forecasted demand in a more abbreviated manner than is typical for similar master plans. The CVG master plan references actions by DHL to expand its cargo facilities, which suggests that DHL rather than the airport may manage and plan its cargo terminals and aprons (CVG master plan, 4-57). Planners summarize the capabilities of cargo infrastructure without explicitly comparing with forecasted demand. It notes that cargo space is available due to Delta Air Lines' drawdown of activity (CVG master plan, 4-60).

#### 7.2.4.5 Land Development

While planners recommend on-airport land uses (CVG master plan, 6-2) and consider the airport's area of effect (CVG master plan, 2-96) and land's development potential (CVG master plan, 2-97), they defer questions of off-airport land development to the OKI Freight Plan, which they reference several times. Published in 2011, the OKI Freight Plan proposes an air cargo park around CVG as "one way to increase [air cargo] business" (OKI Regional Council of Governments 2011). The OKI Freight Plan does not specify implementation steps, nor precisely map or define the air cargo park.

#### 7.2.4.6 Conclusion

One of the CVG master plan's characteristics that sets it apart is its repeated focus on integrators' strategy and needs. Embedding integrators' so deeply into the planning process provides an opportunity to learn customers' needs and trends shaping their business plans.

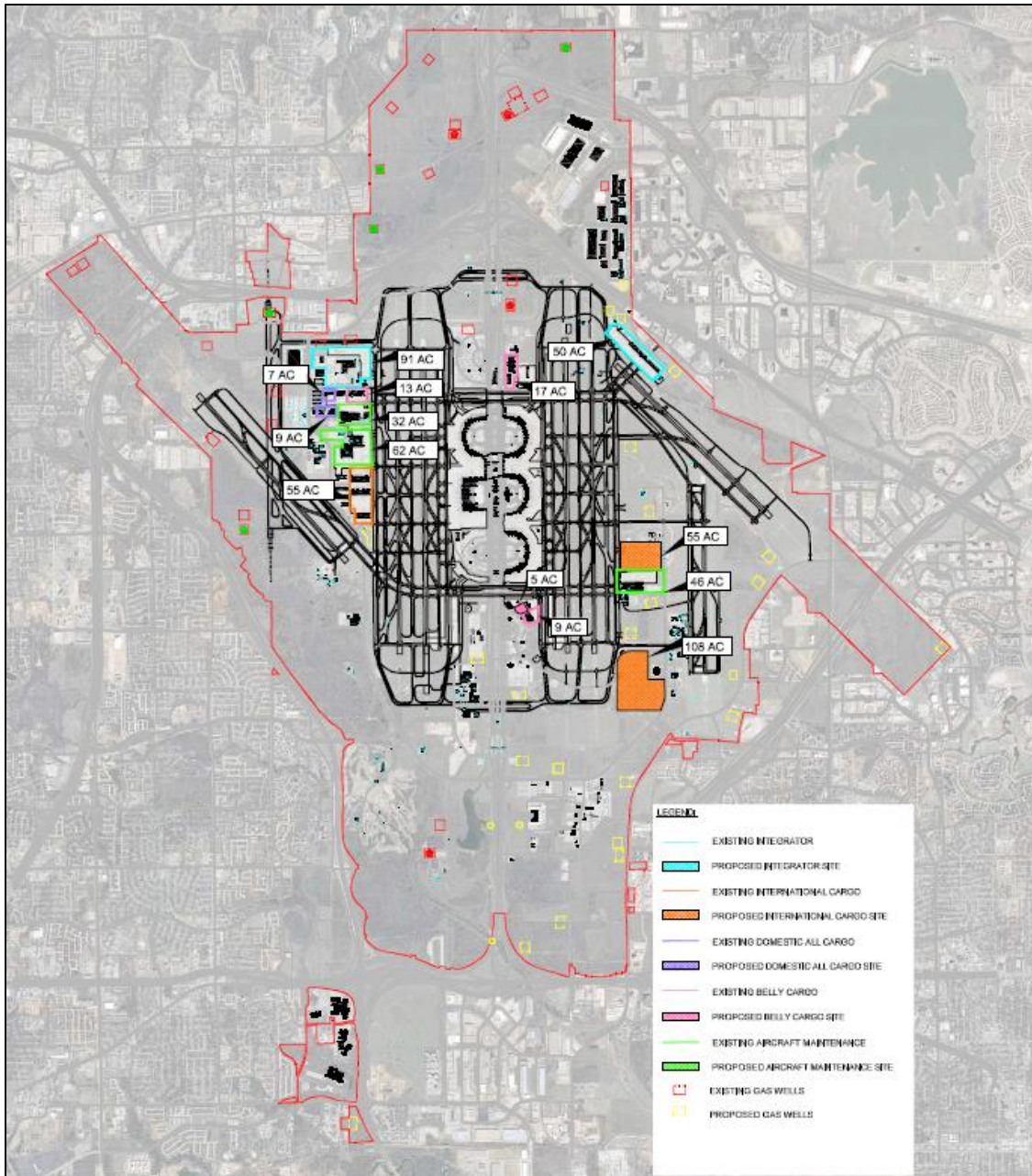
#### 7.2.5 *Dallas/Fort Worth International Airport (DFW)*

The Dallas/Fort Worth region in north Texas is the fourth largest U.S. metro area and contains the fourth busiest airport by passenger volume, the eponymously named Dallas/Fort Worth International Airport (DFW). The region makes up 3% of national GDP (Bureau of Economic Analysis 2016) and 2% of population (U.S. Census Bureau 2015). The region is expanding quickly, having grown its population by 10% and its economic activity by 29% between 2010 and 2015 (Bureau of Economic Analysis 2016). This combined with the region's geographic centrality has made it a very attractive site for e-retailers, both as a customer base and as a hub for national distribution. Companies such as Amazon, GameStop, and Wayfair have established FCs, and a number of e-fulfillment startups also call the region home (Carlisle 2017; Cho and Gales 2014).

DFW airport is unique in part for its enormous land area, which is the second largest in the country, and for its seven runways (Dallas/Fort Worth International Airport 2017). The airport's cargo weight of 670 thousand tons in 2015 makes it the 11<sup>th</sup> busiest in the world (Airports Council International - North America 2015). The airport also hosts a UPS hub. DFW is at the center of one of the country's greatest logistics industry concentrations.



DFW has five parallel runways and two angled runways. It has five passenger terminals and has cargo terminals on the northeast, southeast, and northwest sides of the airport. UPS's terminal is on the northwest side ('AC-91' in Figure 43), while FedEx houses its operations in the terminal labeled '50-AC' on the northeast side. International air cargo is located on the west side of the airport, between runways 18R/36L and 13R/31L. Finally, bellyhold cargo uses two terminals on the north side (17-AC) and on the south side (6-AC). Both terminals are located midfield, which makes access to aircraft parked at the midfield passenger terminals easier than a peripheral location that would require crossing runways.



**Figure 43. DFW Airport cargo sites (actual and proposed preferred alternative).**

**Source: DFW master plan, IV-82.**

The Airport Development Plan Update (hereafter called ‘DFW master plan’) was completed in 2009, updating the previous plan from 1997. It is one of the earliest master plans among those used in the document reviews, but is included because of the region’s

dense concentration of e-fulfillment facilities. The DFW master plan has three phases: scoping and visioning, concept and integrated planning, and developing the passenger terminal concept.

**DFW master plan:** Dallas/Fort Worth International Airport. 2009. “2009 Airport Development Plan Update.”

<https://www.dfairport.com/development/masterplan/index.php>.

#### 7.2.5.1 E-fulfillment Influence

Planners do not reference e-fulfillment specifically. Still, they acknowledge the link between the airport and surrounding logistics activity, saying that "proximity to the Airport drives growth and investment in warehousing, distribution, and logistics facilities" (Dallas/Fort Worth International Airport 2009) (DFW master plan, I-1).

#### 7.2.5.2 Forecasting

Planners develop a base cargo scenario and an alternate scenario. The base scenario employs institutional forecasts, namely averaging the Airbus and Boeing forecasted global cargo growth rates, which results in an annual cargo growth rate of 3.5%. The alternate scenario assumes fast growth by UPS, while educated assumptions about growth rates result in much higher (~18%) growth rates for the first two years and 3.5% growth rates for the remaining years (DFW master plan, IV-78). This forecasting approach does not explicitly account for cargo growth related to e-fulfillment, but it could easily consider integrator reconfigurations in response to e-fulfillment as part of the alternate scenario.

#### 7.2.5.3 Freight Community Involvement

Stakeholders were consulted to develop planning goals, the cost outcome model, and terminal alternatives. Some stakeholder groups are defined as “airline stakeholders,” whereas others are not specified (DFW master plan, III-8). Additionally, unnamed technical consultants provided information on “airside, terminal, landside, baggage handling systems, cargo, and support facilities” (DFW master plan, I-4). UPS was likely a stakeholder and as such may have provided feedback about changes in air cargo related to e-fulfillment, even though the DFW master plan does not specify the airlines consulted.

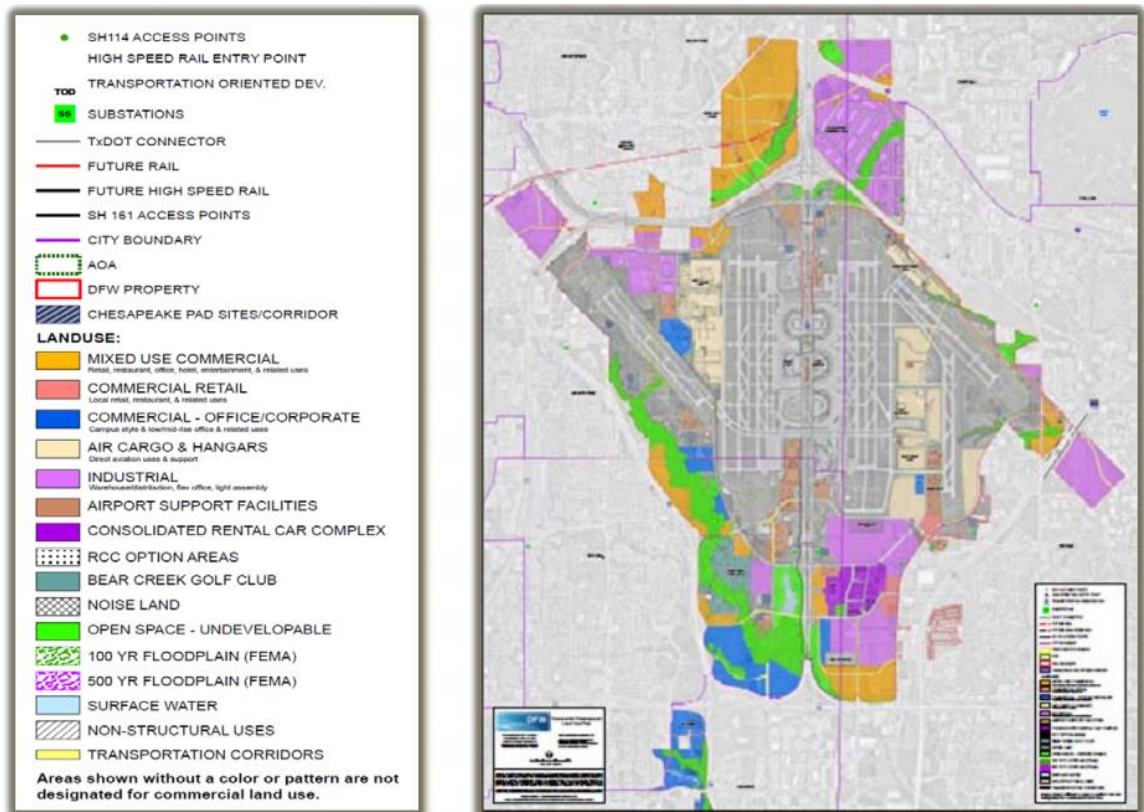
#### 7.2.5.4 Investments and Policies

Planners apply conversion rates to forecast cargo activity and estimate infrastructure needs, and they compare forecasted needs with current capacity. Needs are segmented by air carrier type (e.g., bellyhold, all cargo, and integrator) (DFW master plan, IV-24). Forecasted needs are compared with capacity along the same three categories, using utilization rates to convert cargo volumes to warehouse and aircraft apron needs. Planners propose expanding international air cargo terminals with two new facilities on the east side of the airfield (labeled ‘55 AC’ and ‘108 AC’ in Figure 43 above).

#### 7.2.5.5 Land Development

Planners refer questions of on-airport development to the 2007 Commercial Development Land Use Plan (DFW master plan, I-11), which was updated in 2012 (Dallas/Fort Worth International Airport 2012). The land use plan permits substantial industrial development on airport property, particularly under runway approaches, as

shown in Figure 44. On-airport development is especially important at DFW because of its very large size. The nearest Amazon FC (located at 2700 Regent Blvd, Irving, TX 75063) is in an industrial zone on airport property. The plan does not specifically encourage off-airport development.



**Figure 44. DFW commercial development land use plan 2012.**

**Source: Dallas/Fort Worth International Airport (2012).**

#### 7.2.5.6 Conclusion

DFW Airport already hosts e-fulfillment and will remain an attractive location for e-retailers who wish to have easy access to UPS's air hub. For the most part, e-fulfillment is implicit in the DFW master plan. The lack of explicit mention may be due to the plan's

publication before most of the e-fulfillment expansion that has occurred over the past several years had begun in earnest.

#### *7.2.6 John F. Kennedy International Airport (JFK)*

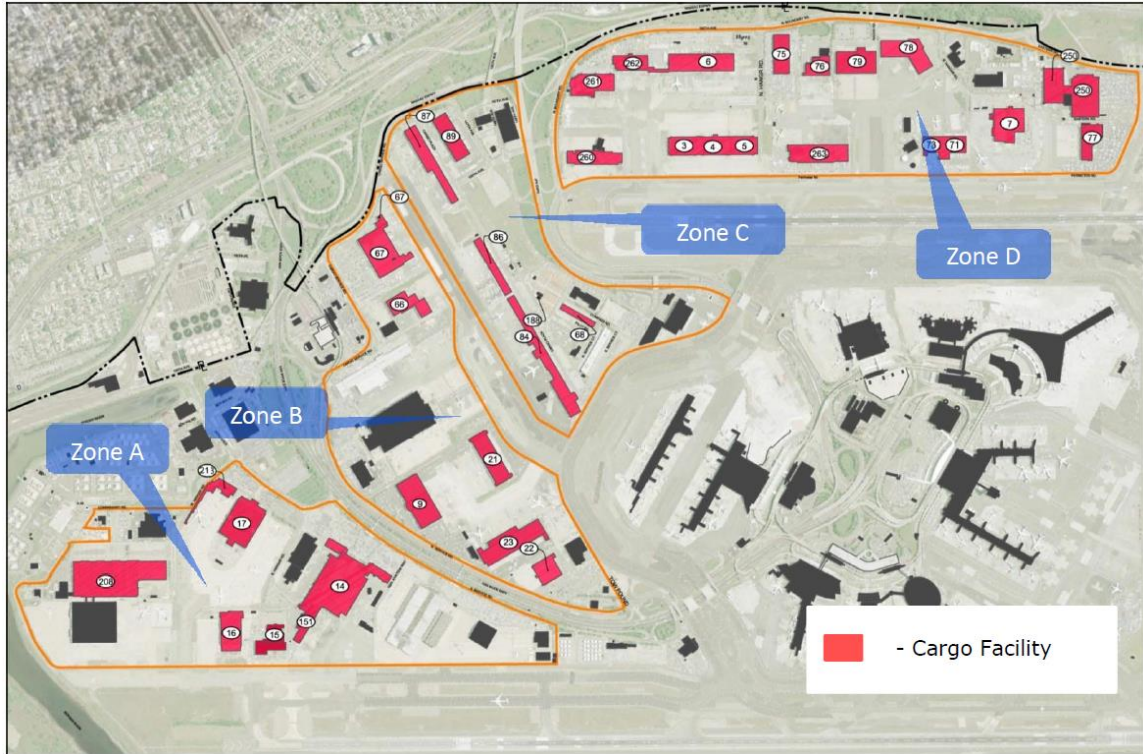
The New York metropolitan region is America's most populous region with the largest regional economy, accounting for approximately 9% of U.S. GDP (Bureau of Economic Analysis 2016) and 6% of the population (U.S. Census Bureau 2017a). The region's size has allowed it to anchor three major commercial airports. New York's John F. Kennedy International Airport (JFK) is one the three major airports owned and operated by the Port Authority of New York and New Jersey (PANYNJ).

JFK Airport has maintained its traditional status as America's largest international air gateway, welcoming passenger and cargo airlines from around the world to create very high international connectivity, with an especially strong presence on the European market. JFK Airport is not dominated by any one cargo airline, but rather has attracted large cargo volumes from many U.S. and international airlines, using both bellyhold capacity and dedicated freighters. Eighty-four airlines from six continents serve the airport (Port Authority of New York & New Jersey 2017). American Airlines carries the most cargo weight, followed by FedEx, Delta Air Lines, China Airlines, and Korean Air (New York City Economic Development Corporation and Port Authority of New York & New Jersey 2012) (JFK Air Cargo Study, p. 36). Nonetheless, air cargo consolidation, fuel price volatility, security costs, and a shipper preference for cheaper ground transportation have reduced cargo traffic at many airports, including JFK, which lost 20% of its cargo tonnage between 2006 and 2015 (Airports Council International - North America 2015; New York

City Economic Development Corporation and Port Authority of New York & New Jersey 2012). There are relatively few sites available near the airport for logistics activity because of the region's dense development. Moreover, freight access to the airport is hindered by the city's requirement that trucks use a very limited set of truck routes (NYC DOT 2017).

Although JFK Airport does not host an integrator air hub, both major air integrators are present, and it has very large bellyhold and freighter capacity. The airport has two sets of parallel runways and several separate passenger terminals. The very extensive cargo terminals are spread over four zones with nearly 28 million square feet of space for cargo, as shown in Figure 45 (JFK Air Cargo Study, chapter 6, p. 2). Zone A primarily serves Port Authority administration and Japan Airlines; zone B serves domestic carriers; zone C serves Danzas AEI Emirates, now known as DHL Global Forwarding; and zone D serves FedEx and several other airlines. Many buildings were built for specific carriers who no longer use them, and many require renovation to achieve modern operating standards (JFK Air Cargo Study, chapter 6).





**Figure 45. JFK Airport cargo zones.**

**Source: JFK Air Cargo Study, chapter 6, p. 3.**

The JFK Air Cargo Study was completed in 2012 as a joint effort of the Port Authority of New York and New Jersey (PANYNJ) and the New York City Economic Development Corporation. Compared with other airports' master plans, the JFK Air Cargo Study exhibits a greater concern with maintaining the airport's competitive edge and generating economic opportunities for the neighborhood and city. The study examines the air cargo market and JFK Airport's place in it to determine if the airport "can regain the levels of cargo activity that have been lost" and "identify the strategies and specific initiatives that the City and the Port Authority should pursue" (JFK Air Cargo Study, Executive Summary p. 2).



**JFK Air Cargo Study:** New York City Economic Development Corporation, and Port Authority of New York & New Jersey. 2012. “JFK Air Cargo Study.” Technical Report. <https://www.panynj.gov/airports/jfk-lga-master-plan-design-competition.html>.

#### 7.2.6.1 E-fulfillment Influence

Planners address e-fulfillment’s influence on air cargo and its presence in the New York region. Planners treat e-commerce as one of the ten “critical cargo variables” that influence air cargo shipments and are present at JFK Airport (JFK Air Cargo Study, chapter 2, p. 3). Specifically, the JFK Air Cargo Study says—

“E-Commerce. Many of the shipments generated by home shopping networks, catalogue shopping, and most recently, e-commerce, require specialized facilities for efficient processing and expedited delivery. Accordingly, these shipments have a greater tendency to move by air or expedited trucking. This has accelerated demand for air cargo operations in general and integrator operations in particular. Much of this fulfillment requirement is met by businesses concentrating operations on or near airports” (JFK Air Cargo Study, chapter 2, p. 5).

#### 7.2.6.2 Forecasting

Planners create three air cargo scenarios with low, moderate, and high annual growth rates. The growth rates are based on previous analysis conducted by the PANYNJ that examined time-series cargo data for sensitivity to factors such as competition from other modes, changes in fuel cost, competition from other gateways, and the relative

strength or weakness of demand for transportation to/from Europe and Asia (JFK Air Cargo Study, chapter 6, p. 44). E-fulfillment is not explicitly considered in scenario creation.

#### 7.2.6.3 Freight Community Involvement

Planners surveyed and interviewed freight generators, carriers, and handlers to “identify operating requirements, necessary facility enhancements, areas of concern, and primary strengths of the Airport” (JFK Air Cargo Study, chapter 3, p. 1). The extensive freight community involvement includes shippers, carriers, and other tenants. There were at least three types of airport user involvement. First are in-person interviews. The planners made presentations to the cargo community and discussed the planning processes and goals with “cargo personnel from most of the Airport’s carrier population as well as a number of regional freight forwarders and customs brokers” (JFK Air Cargo Study, chapter 3, p. 2). Second are phone interview, which planners conducted with 21 cargo station managers. The interviews discuss the adequacy of the airport’s landside and airside facilities, ground access to the airport, airport operations, airport and regional policies, airport costs, regional costs, ease of doing business, government considerations, economic development considerations, and the airport’s relationship with the two other PANYNJ airports that host freighters (EWR and SWF) (JFK Air Cargo Study, chapter 3, p. 17). Finally, planners conducted a survey of the “[cargo] community at large.” A wide variety of cargo organizations were invited to participate (JFK Air Cargo Study, chapter 3, p. 2). The freight community involvement may have included e-retailers and / or carriers able to represent e-fulfillment trends and needs. For instance, carriers may have been able to convey trends related to e-fulfillment and e-retailers’ needs.

#### 7.2.6.4 Investments and Policies

Planners compare existing infrastructure capacity with infrastructure needs based on forecasts (JFK Air Cargo Study, chapter 6). Planners use facility planning utilization rates to convert cargo tonnage for different types of carriers to facility square footage needs (JFK Air Cargo Study, chapter 6, p. 48), and they estimate warehouse, office, aircraft parking, trucking, and other facilities requirements as a function of forecasted cargo volume (JFK Air Cargo Study, chapter 6).

Several other aspects set the study apart from typical airport master plans. Cargo's institutional place within the managing organization receives much more attention than is typical for a cargo plan. The JFK Air Cargo Study recommends that the PANYNJ establish cargo as a "business center" with revenue targets and powers to achieve them, develop a single cargo vision for the PANYNJ, and give cargo a marketing budget (JFK Air Cargo Study, Section A, p. 2 and p.12).

Detailed policy recommendations address a multitude of ways to streamline cargo, related to the provision of physical infrastructure and services for cargo, tenant relations, landside access to cargo facilities, marketing, and off-airport services. These policy recommendations do not mention e-fulfillment by name, but they would doubtlessly improve e-retailers' access because they address issues such as landside ground transportation to off-airport warehouses.

#### 7.2.6.5 Land Development

Ensuring adequate land for airport-related functions like logistics occupies a major portion of the JFK Air Cargo Study because of the airport's location in a dense metropolis. Much off-airport land is already developed. Nonetheless, planners recommend rationalizing the allocation of airport property to accommodate cargo-generating functions (JFK Air Cargo Study, Executive Summary, p. 4; Section A, p. 1 and p. 5). They also encourage off-airport concentrations of cargo-generating activity under the brand "cargo village." Planners assess the market feasibility of specific properties near the airport for cargo-generating activity (JFK Air Cargo Study, chapter 8, p. 21).

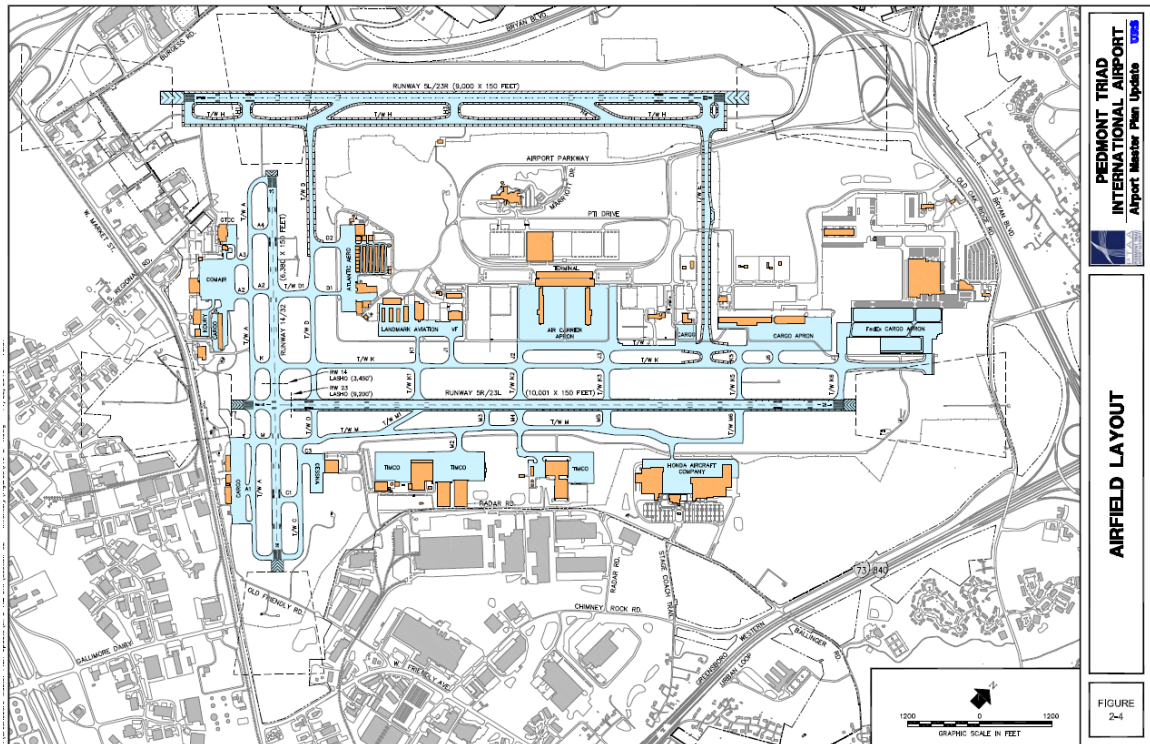
#### 7.2.6.6 Conclusion

The JFK Air Cargo Study is one of the few studies that treats e-fulfillment explicitly as an influence on air travel and creates plans to encourage logistics at the airport. The JFK Air Cargo Study also seeks to overcome the logistics-related challenges imposed by its location within a highly built up metropolitan area with constrained land supply.

#### 7.2.7 *Piedmont Triad International Airport (GSO)*

The Piedmont Triad International Airport (GSO) is in the Triad region among the cities of Greensboro, Winston-Salem, and High Point, NC. The Greensboro-Winston-Salem-High Point Combined Statistical Area has 1.6 million residents (U.S. Census Bureau 2015). The region's economy traditionally centered on tobacco, furniture, and textiles, and in the wake of their decline the region has instead encouraged technology, education, logistics, and healthcare (City of Greensboro, n.d.).

GSO airport is the country's 42<sup>nd</sup> busiest U.S. airport by cargo landed weight, and it is the 97<sup>th</sup> busiest passenger airport, with 850 thousand enplaned passengers in 2016 (Federal Aviation Administration 2016). The airport hosts a FedEx hub and many aviation-related activities, including the U.S. headquarters and manufacturing center of the Honda Aircraft Company (Honda Aircraft Company 2017). The airport has two parallel runways, one of which opened in 2010 for the FedEx hub. There is another shorter perpendicular runway. There are two main cargo terminals, both located on the north side of the airfield (right of Figure 46). One terminal is dedicated to FedEx, and the other serves the remaining cargo carriers. There is a midfield passenger terminal, and several related operators on the airport's periphery, especially on the east and south sides.



**Figure 46. GSO airport layout.**

**Source: GSO master plan, 2-4.**

The Airport Master Plan Update and Strategic Long-Range Visioning Plan (hereafter called the “GSO master plan”) was published in September 2010. The last master plan update was begun in 1997 but was suspended when FedEx selected the airport as its Mid-Atlantic hub because of the changes required to accommodate FedEx (GSO master plan, 1-2). Major construction projects have occurred since the plan was suspended, including building passenger terminal expansions, FedEx’s new facilities, the Honda Aircraft Company’s headquarters, and a new parallel runway (runway 5L/23R) (GSO master plan, 1-3).

Airport-centric development concepts under the Aerotropolis brand are incorporated into the GSO master plan in several ways. First, the plan built upon a 2008

study called “The Piedmont Triad Aerotropolis Plan: From Guidelines to Implementation” (Kasarda and Appold 2008). Second, the GSO master plan includes an appendix (“Appendix H: Strategic Long-Term Planning Considerations Report”) by Kasarda, Appold, and Howell that provides guidance about the airport’s potential to induce regional economic development.

**GSO master plan:** Piedmont Triad International Airport. 2010. “Airport Master Plan Update and Strategic Long-Range Visioning Plan.”  
<http://airportmasterplan.homestead.com/Index.html>.

**Aerotropolis plan:** Kasarda, John D., and Stephen J. Appold. 2008. “The Piedmont Triad aerotropolis plan: From guidelines to implementation.” Kenan Institute of Private Enterprise, University of North Carolina at Chapel Hill. Retrieved from <http://www.cityofws.org/Portals/0/pdf/transportation/forms-reports/lrtp/2035updatefinal/appendix/triadaerotropolisplan.pdf>.

#### 7.2.7.1 E-fulfillment Influence

The GSO master plan explicitly states that the airport’s integrator air hub has the potential to attract logistics facilities, including FCs. The airport authority believes that FedEx’s hub can “generate significant economic development on and near the airport” (GSO master plan, 1-6). Specifically, it says that—

“Economic development experts predict that the presence of the Mid-Atlantic FedEx hub will attract new businesses that depend on overnight shipping, as have

other major FedEx hubs located in Fort Worth, Texas and Indianapolis” (GSO master plan, 5-5).

A similar idea is restated in Appendix H as a “potential catalytic effect associated with the FedEx sort hub” (GSO master plan, Appendix H, p. 6), which will influence firm location and future flows of passengers and cargo (GSO master plan, Appendix H, p. 7). Appendix H asserts that a larger hub with more international connections will attract more FCs (GSO master plan, Appendix H, p. 8 and p. 16).

#### 7.2.7.2 Forecasting

Cargo activity is forecast in three separate segments: FedEx cargo, other cargo, and belly freight. Of these three, FedEx cargo is the only one that may account for e-retail cargo or be easily adaptable to consider it, although it is not clear from the GSO master plan exactly how FedEx cargo was forecast. FedEx forecasts appear to assume steady volume that is insensitive to changes wrought by e-fulfillment growth. Growth rates for other cargo carriers are derived by averaging domestic forecasts by Boeing and Airbus (GSO master plan, E-37). Cargo tonnage estimates were converted to estimates of aircraft activity by applying historical ratios of cargo handled per operation (GSO master plan, E-38). Belly freight is forecast based on the passenger aircraft operations, both in number and types of aircraft (GSO master plan, E-37). Belly freight capacity is likely to keep falling since most passenger growth is forecast to occur aboard regional turboprops without substantial cargo capacity (GSO master plan, E-37).



#### 7.2.7.3 Freight Community Involvement

The GSO master plan does not appear to involve input from shippers. While it is almost certain that the planners solicited feedback from FedEx and possibly other cargo representatives, their involvement is not documented in the GSO airport plan. Airport planners made presentations to stakeholders to gather feedback, several of whom could represent freight interests: the North Carolina Board of Transportation, nearby metropolitan planning organizations, economic developers, and the High Point Chamber of Commerce (GSO master plan, 1-16).

#### 7.2.7.4 Investments and Policies

Airport planners are seeking to preserve land around the airport to allow for future expansion. Since most of potential development sites are off airport property, airport planners recommend coordination with local land use planners for airport expansions whose planning horizon exceeds 20 years (GSO master plan, 1-6). Without such coordination, land may not be available for the airport to develop necessary infrastructure or for aviation-related businesses to grow. Airport planners are also seeking to acquire land for long-term infrastructure or development (GSO master plan, Figure 6-3), such as a third parallel runway.

#### 7.2.7.5 Land Development

The GSO master plan includes a detailed proposal to expand and use airport property for airport-related functions, which explicitly include e-fulfillment. Planners want

to encourage airport-related activities to locate near the airport, and they propose purchasing land for that purpose. Specifically, the plan says the following.

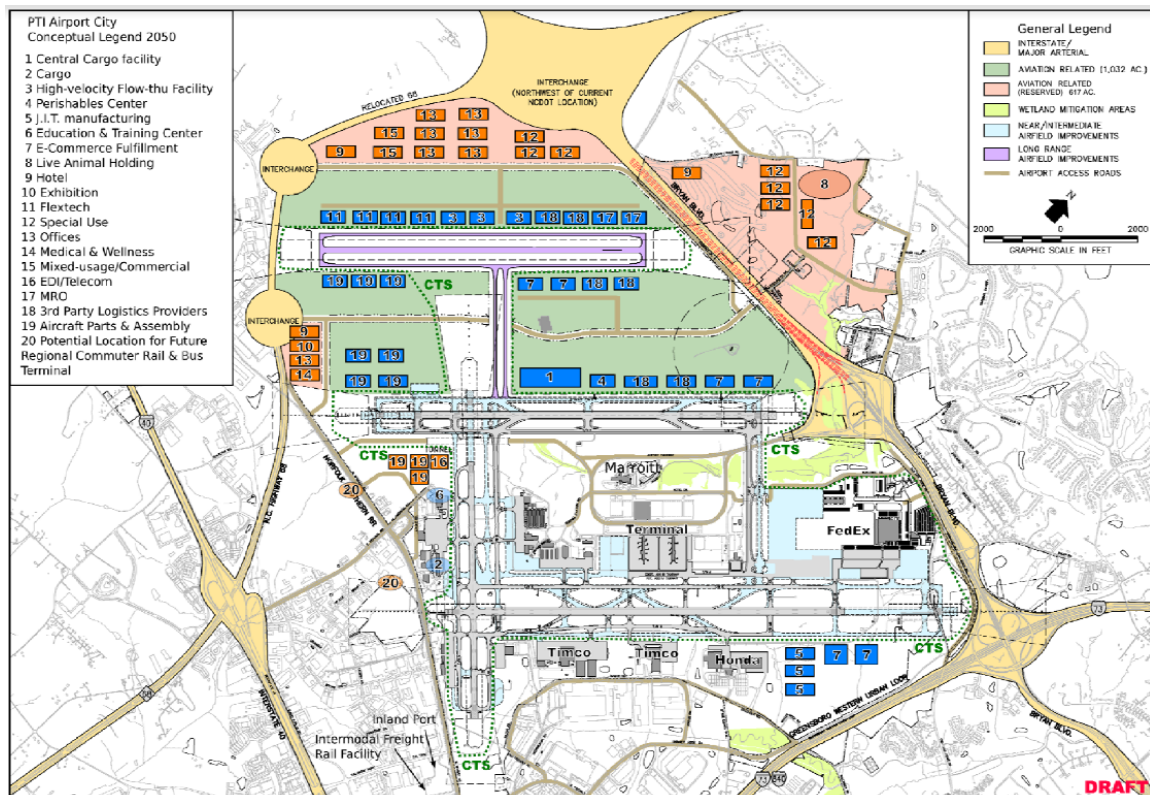
“In its role as an economic generator, the airport has few remaining undeveloped on-airport sites that can accommodate aviation-related activities that desire an airport location. The airport needs to identify additional land that may be purchased for future development of aviation-related industrial use” (GSO master plan, 1-7).

Airport leadership has a stated goal of generating economic development around it that conform with the Aerotropolis concept. They seek to “develop and maintain the ability to facilitate airport land acquisition and facility development that are compatible with the Aerotropolis concept” (GSO master plan, 1-10).

To support these aims, planners estimate on-airport land needs for GSO tenants, focusing on functions that require airfield access and promote economic development. For instance, the FedEx hub will eventually require 250 more acres of airport property (GSO master plan, 5-1). Undeveloped airport land is categorized for development potential in one of several ways that include airport-related uses and aviation support activities (GSO master plan, Figure 5-2).

Appendix H foresees the possibility of on-airport e-fulfillment activity if e-retailers desire close airport proximity (GSO master plan, Appendix H, p. 23). Appendix H states that, by 2050, there is a possibility of the 20 thousand people being employed on the airport in aircraft parts and aircraft assembly, logistics, and e-fulfillment, and that planning must occur to realize this potential [“If such planning and land acquisition does not take place, this special opportunity could be lost forever”] (GSO master plan, Appendix H, p. 24).

Implementation steps are unclear. Finally, Appendix H includes a conceptual map of how the airport might be arranged at build-out, including the aviation-related uses that could occur on airport property. The build-out concept map (Figure 47) explicitly includes several e-fulfillment facilities adjacent to taxiways on airport property (GSO master plan, Appendix H, p. 35).



**Figure 47. GSO draft airport land use concept.**

**Source: GSO master plan, Appendix H, p. 35.**

#### 7.2.7.6 Conclusion

The GSO master plan proposes land and economic development strategies that include e-fulfillment, which is indicative of the Aerotropolis concept that shaped it.

Implementation steps are unclear. Other sections cannot be evaluated because the plan omits details of study execution, notably around stakeholder involvement.

#### *7.2.8 Rickenbacker International Airport (LCK)*

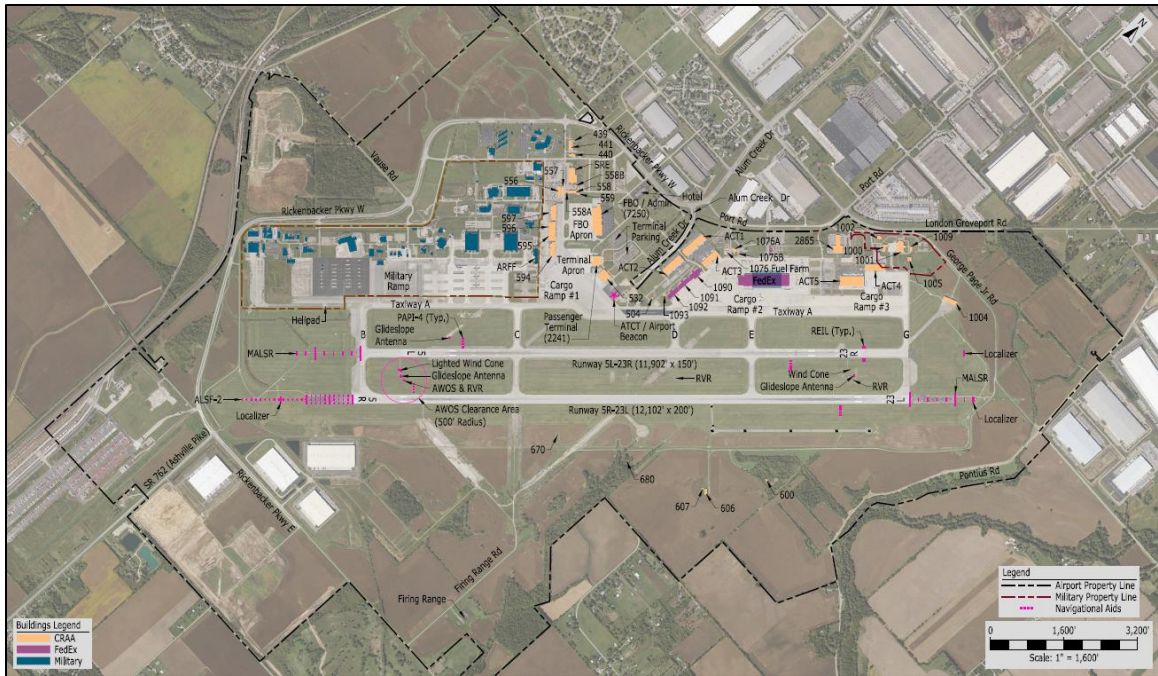
Located next to Columbus, OH, Rickenbacker International Airport is one of the few commercial airports in the United States that specializes in air cargo. It hosts regional cargo airlines including Castle Aviation and AirNet Express; integrators UPS and FedEx; and dedicated freighters from airlines like Kalitta Air, Cargolux, Cathay Pacific Cargo, Emirates SkyCargo, Ethiopian Cargo, and Etihad Cargo (Columbus Regional Airport Authority 2017c). In fact, according to the draft master plan, “LCK landed more air cargo than any other Ohio airport in 2015” (Rickenbacker International Airport 2017). Allegiant Air, a low-cost passenger carrier, also serves ten mostly beachfront destinations (Allegiant Air 2017).

The Columbus Regional Airport Authority, which manages the airport, has aggressively developed a logistics cluster around the airport comprised of the airport’s own dedicated cargo facilities, a logistics park, nearby highway connections, and the adjacent Norfolk Southern Rickenbacker Intermodal Terminal. The combination of air and ground connectivity together with the airport’s central location has drawn many logistics facilities into the Rickenbacker Inland Port, and the authority sells and leases landside and airside properties for cargo-related development (Cushman & Wakefield 2017). The DCs and freight forwarders within the Rickenbacker Inland Port employ over 7,000 people, far more than any other industry in the inland port (Columbus Regional Airport Authority 2017a).

The Columbus region has substantial logistics activity, as evidenced by high logistics location quotients (Bureau of Labor Statistics 2017b).

Planners began the master planning process in September 2016, and as of December 2017 they had published the first three chapters (Inventory of Existing Conditions, Aviation Forecasts, and Facility Requirements), which are analyzed in this section. Remaining chapters will be released progressively.

The airport has two parallel runways, cargo ramps and facilities on its northwest side, as well as a small passenger terminal. Rickenbacker National Guard Base occupies the southwestern-most portion of the aircraft ramp. FedEx also operates an airside facility on the airport's northern side. Figure 48 displays the airport's layout, with the Norfolk Southern Rickenbacker Intermodal Terminal visible in the image's lower left and logistic park warehouses in the upper right. Much of the Rickenbacker Inland Port's property has already been sold or leased for warehouses.



**Figure 48. LCK airport master plan area.**

**Source: LCK plan, Figure 1-4.**

**LCK plan:** Rickenbacker International Airport. 2017. “Airport master plan.”

<http://rickenbackermasterplan.com>.

#### 7.2.8.1 E-fulfillment Influence

The chapter on the Inventory of Existing Conditions (chapter 1) lists e-commerce as one of nine opportunities, in addition to military collaboration, nearby workforce, and others. Moreover, the draft inventory lists several of the Columbus Regional Airport Authority’s goals, to include “becom[ing] an air hub for Amazon.” Even though Amazon later selected Cincinnati (CVG) as its air hub, the statements demonstrate that e-commerce and e-retail traffic are on the planning staff’s and the airport authority’s mind. The forecast section says it even more clearly: “the growth of worldwide e-commerce also has the

potential to capture tremendous opportunities for LCK” (LCK plan, 2-1). Planners believe that cross-border e-commerce can generate much more air activity at LCK than domestic e-commerce. Integrators prefer using trucks to bring items to and from their hubs, so “much of the increases in domestic e-commerce will be moved using [integrators’] ground and intermodal networks” (LCK plan, 2-44).

In addition, the Forecasting chapter (chapter 2) also indicates that LCK has already been approached by e-commerce / e-retail vendors, including one “who has a strong presence in JFK and LAX [and] has indicated the need for a mid-country processing and sortation center.” Another e-commerce prospect for the region has requested approval for an express consignment carrier facility, which would allow foreign e-commerce shippers “cost-effective clearance and expedited domestic delivery by postal services (USPS) or regional last-mile carriers” (LCK plan, 2-41). The planners also account for possible growth in international e-commerce / e-retail shipments, expecting growth of 15% annually through 2020, especially between the U.S., China, and Europe. Some cross-border traffic might come from e-retail aggregators already present in the Columbus region. Aggregators accept shipments from multiple retailers for the same overseas customer and consolidate them for onward shipment to the customer’s country of residence (LCK plan, chapter 2, 2-41).

#### 7.2.8.2 Forecasting

Planners acknowledge in chapter 2 that e-fulfillment complicates forecasting. Cargo volumes are forecast with three scenarios: aggressive growth, moderate growth, and low growth. No scenario assumes constant cargo activity or declines at any point in the

forecast horizon. Instead of working from macro-data or macro-projections for the entire industry or region, planners adopt a micro-scale approach, analyzing distinct activities that could drive cargo growth and specific firms in industries that may expand their presence at LCK. Some of these firms have contacted LCK staff or visited the airport or logistics park as prospective tenants. Planners estimate high, low, and moderate growth rates for each activity from quantitative data and interviews. The analysis is detailed, estimating the number of packages that would be transported and the number of weekly flights required based on a certain capture of these companies' activity. These estimates are aggregated to produce the forecasts. Table 21 displays the assumptions. The assumptions inform forecast growth rates. Forecasts are based on constant growth rates for freighters and integrators for five- to ten-year timeframes.

**Table 21. Phenomena considered in LCK's aggressive growth scenarios.**

<b>Activities (and Page Numbers)</b>	<b>Assumptions (Aggressive Scenario)</b>	<b>Area of Impact</b>
LCK as a supplementary international gateway for Forward Air Freight (FAF) (2-39)	5% capture of weekly sort conducted by FAF	Exports
Express consignment carrier facility (ECCF) at LCK (2-42)	Increase of 50,000 packages delivered inbound per day to new ECCF facility	Imports
E-fulfillment and other functions requiring a geographically central hub (2-42)	Continued business development efforts in catchment area	Imports and Exports
Freight forwarder global hub (2-27)	One 'global freight forwarder'/3PL reroutes ORD/JFK cargo to LCK	Imports and Exports
"Mid-country" gateway (2-42)	One new operation for incremental growth of ECCF e-commerce cargo	Imports
E-commerce aggregators (2-41)	One export, e-commerce aggregator operating at LCK	Exports



#### 7.2.8.3 Freight Community Involvement

The planners' micro-level approach to forecasting cargo activity requires detailed knowledge of each activity's functioning and growth trajectories. Therefore, it is not surprising that the planners conducted "interviews with freight stakeholders and cargo owners" (LCK plan, 2-46). The document does not explicitly describe data sources. Planners' interviews with freight stakeholders or LCK staff's previous meetings with them likely produced some of the data employed. For instance, the plan says that "one global e-commerce provider alone estimates that [an ECCF] would need to process up to 50,000 packages per day" (LCK plan, 2-42).

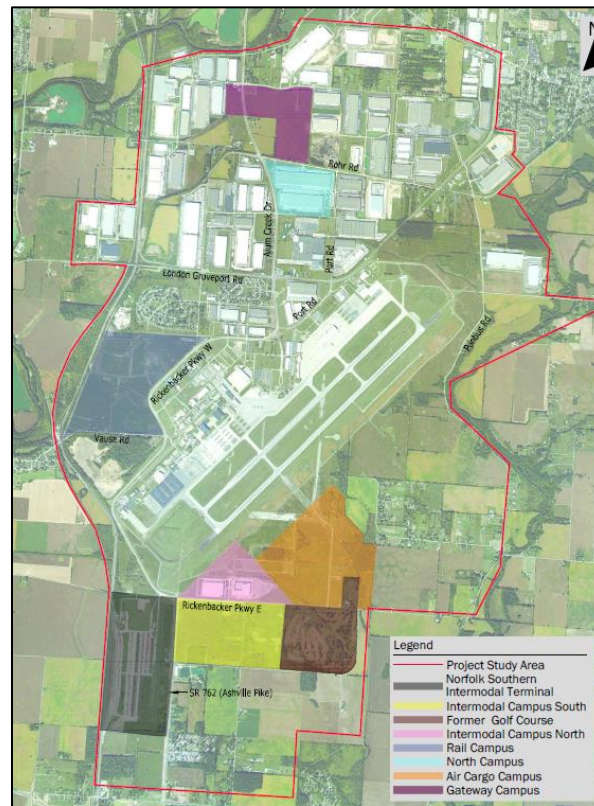
#### 7.2.8.4 Investments and Policies

Investments and policies cannot be evaluated as the relevant chapters have not been released. Notwithstanding, the chapter on Facility Requirements (chapter 3) shows that planners are evaluating facility requirements based on forecast aircraft activity using industry-accepted practices.

#### 7.2.8.5 Land Development

The first three chapters of the LCK plan do not address land development. The airport is embedded in the Rickenbacker Inland Port, which includes the Rickenbacker Global Logistics Park with 70 million square feet of logistics facilities and the possibility of another 30 million square feet of logistics facilities (Columbus Regional Airport Authority 2017b). All but a few of the logistics facilities are off airport property, and the plan depends on the action of "the CRAA Business Development staff, and others in the

community who have economic development responsibilities” to realize the aggressive cargo growth scenario (LCK plan, 3-33). Therefore, the plan leaves cargo generation and the attraction of cargo-generating logistics facilities as the responsibility of the appropriate airport and logistics park staffs.



**Figure 49. Map of Rickenbacker Inland Port.**

**Source: LCK plan, Figure 1-3.**

#### 7.2.8.6 Conclusion

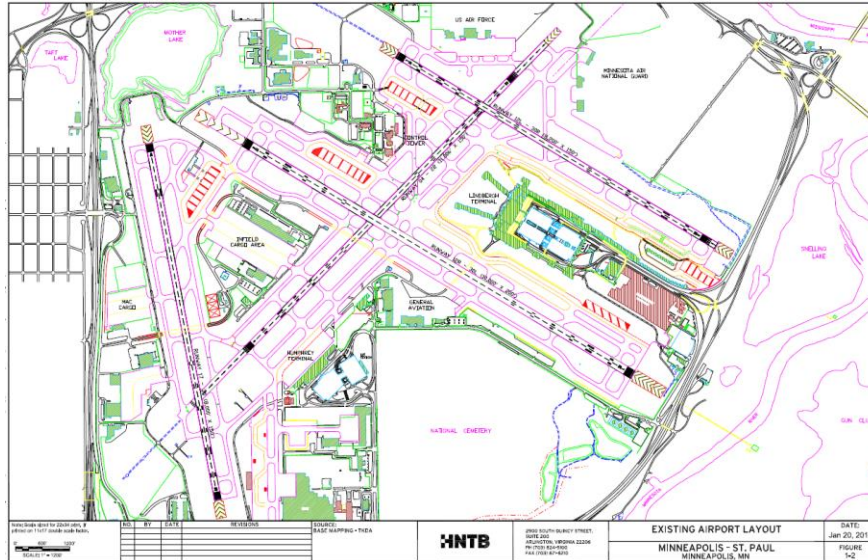
Planners at LCK adopt a different approach from many airport plans by conducting micro-level analysis of individual companies and types of logistics activity rather than macro-scale trends affecting cargo at the regional or national level. Moreover, the airport’s

relatively small size and outsized cargo focus make cargo trends including e-fulfillment appear very frequently in the report.

#### *7.2.9 Minneapolis – St. Paul International Airport (MSP)*

The Minneapolis – St. Paul International Airport (MSP) is south of downtown Minneapolis and southwest of St. Paul in the country's 13<sup>th</sup> largest regional economy. Population has grown 6% between 2010 and 2016 to over three and a half million people. The region hosts a moderately sized e-fulfillment cluster, with several Amazon FCs and at least one Target FC.

MSP airport is the 16<sup>th</sup> busiest U.S. passenger airport, with some 37 million annual passengers, and it is the 25<sup>th</sup> busiest U.S. cargo airport, with 200 thousand annually emplaned cargo tons (Airports Council International - North America 2015). Delta Air Lines accounts for 71% of the airport's passenger activity (Gieseke 2016) and a similar or larger proportion of its bellyhold capacity. The MSP airport was the long-time hub of Northwest Airlines, and it has remained a hub for Delta Air Lines since their 2009 merger. The main cargo airlines serving the airport are DHL, UPS, and FedEx, as well as associated subsidiaries. MSP airport features two passenger terminals and four runways, of which two are parallel. Facilities for the U.S. Air Force and Minnesota Air National Guard are located on the airfield's north side. UPS and FedEx use the Infield Cargo Area located in the triangle among runways 12R/30L, 17/25, and 4/22. Delta Air Lines' cargo terminal is south of Humphrey's passenger terminal, adjacent to the national cemetery. DHL uses the Metropolitan Airport Commission's (MAC) cargo terminal on the airfield's westernmost side. Figure 50 displays the airfield's layout.



**Figure 50. MSP airfield map.**

**Source: MSP plan, chapter 3, p. 7.**

The MSP Long Term Comprehensive Plan Update (hereafter called the “MSP plan”) was completed in 2010 and updates the previous version from 1996, during which time the aviation industry had experienced major changes related to the attacks of September 11<sup>th</sup>, the merger of its largest airline, new aircraft types, and other new dynamics that changed many of the assumptions upon which the 1996 plan was founded (MSP plan, chapter 1, p. 1).

**MSP plan:** Metropolitan Airports Commission. 2010. “Minneapolis-St. Paul International Airport (MSP): 2030 Long Term Comprehensive Plan Update.”  
<https://www.msppairport.com/about-msp/airport-improvements.aspx>.

#### 7.2.9.1 E-fulfillment Influence

The plan is passenger-focused and does not consider freight dynamics. There was a previous cargo study released in 2001 titled the *Minneapolis – St. Paul Air Cargo Study*

that recognized e-commerce as a force in air cargo. Specifically, the cargo study said that “airfreight, which is a critical part of global distribution and a fundamental enabler of e-commerce, is doubling in volumes every ten years.” The remark does not appear to have shaped the 2001 cargo study’s methods or influenced the 2010 MSP plan.

#### 7.2.9.2 Forecasting

Cargo activity is not forecast based on cargo dynamics but instead through a constant multiplier applied to passenger activity. While the passenger forecasts are rigorous, they cannot account for cargo-specific dynamics such as e-fulfillment. Belly cargo is forecast by applying a multiplier to domestic passenger forecasts that converts (passenger) available seat miles (ASMs) to (cargo) revenue ton-miles (RTMs). Passengers are forecast independently for several segments (e.g., domestic vs. international, originating vs. connecting) with econometric models that consider such factors as regional income, competition, and hubbing. In some cases, they are compared with growth forecasts by the FAA, Boeing, and Airbus (MSP plan, chapter 2, p. 46).

#### 7.2.9.3 Freight Community Involvement

There was very limited freight community involvement, and the plan cites no involvement of e-retail shippers or carriers. Planners held meetings with neighboring cities to receive informal feedback. The Metropolitan Council Transportation Advisory Board met with planners (MSP plan, chapter 8, p. 176), and one member represents the freight transportation industry (Metropolitan Council 2013), which appears to be the extent of freight involvement in the planning process.

#### 7.2.9.4 Investments and Policies

The MSP plan exclusively considers passenger infrastructure and does not consider freight infrastructure (MSP plan, chapter 3). None of the alternatives relate to freight infrastructure (MSP plan, chapter 4).

#### 7.2.9.5 Land Development

Land use compatibility analysis was performed to assess impacts of the airport related to noise and pollution (MSP plan, chapter 6). There was no attempt to study how the airport might impact nearby land use or preserve land on or around the airport for aviation-related uses.

#### 7.2.9.6 Conclusion

The MSP plan is a robust analysis to prepare for passenger growth at MSP airport. Freight was not a focus for the plan, and freight dynamics such as e-fulfillment are not captured in forecasts, analysis, or recommendations.

#### 7.2.10 *Phoenix Sky Harbor International Airport (PHX)*

Phoenix Sky Harbor International Airport (PHX) is the 20<sup>th</sup> busiest cargo airport in the country with nearly 300 thousand tons processed cargo in 2015. It is even larger on the passenger side, as the 11<sup>th</sup> busiest passenger airport with 44 million annual passenger (Airports Council International - North America 2015). It is a hub for American Airlines and has significant volume due to Southwest Airlines. On the cargo side, Ameriflight operates a regional hub (Ameriflight 2017), but Ameriflight flies very small aircraft on

niche routes and makes up just 2% of the airport's cargo tonnage. As of 2012, FedEx, UPS, and DHL together transported some 71% of cargo tonnage. The remaining 27% of cargo tonnage was moved as bellyhold freight (Phoenix air cargo study, ES-6). The airport's cargo terminals are in two zones on the west and south sides of the airport (Figure 51). The airport has three parallel runways and several midfield passenger terminals.



**Figure 51. PHX airport aerial view with cargo areas designated.**

**Source: PHX cargo study (ES-11).**

The Phoenix region is one of the fastest growing in the country. In fact, Maricopa County, where Phoenix is located, was the fastest growing county by population in 2016 (U.S. Census Bureau 2017b). The region itself has slightly fewer than 5 million people, which has increased by 10% in just six years (U.S. Census Bureau 2017a). The region is home to 1.4% of the country's population and 1.2% of its GDP (Bureau of Economic Analysis 2016). The Phoenix region has attracted a growing e-fulfillment footprint, with

four Amazon FCs, FCs serving Dick’s Sporting Goods and Macy’s, and a new UPS facility to process e-retail shipments (Sunnucks 2017).

The Phoenix Regional Air Cargo Planning Study (hereafter called the “PHX cargo study”) was written by InterVISTAS Consulting Group and released in 2014 by the City of Phoenix Aviation Department. It aims to understand the market for air cargo transport in Phoenix and identify infrastructure needs to support demand (PHX cargo study, ES-1).

**PHX cargo study:** InterVISTAS Consulting Group. 2014. “Phoenix Regional Air Cargo Planning Study.” Phoenix Sky Harbor International Airport.

#### 7.2.10.1 E-fulfillment Influence

The PHX cargo study highlights e-fulfillment as one of the growth opportunities for the PHX area. As early as page 3, it defines e-fulfillment as a growing industrial concentration in the Phoenix area, and a potential source of air cargo demand, saying—

“A notable group of shippers that are relatively new to the market are online retailers that have established distribution centers in the Phoenix area. While these retailers do not manufacture goods in the region, their presence is growing along with their needs to ship items by air and other modes from the Phoenix area” (PHX cargo study, p. 3).

Moreover, the PHX cargo study shows that it understands the dynamics behind e-retail shipments when it outlines conditions in which shippers may opt for air cargo (e.g., high value-to-weight ratio, potential for theft), including the condition that applies to e-fulfillment (e.g., “demand is less predictable”) (PHX cargo study, p. 18). Planners believe



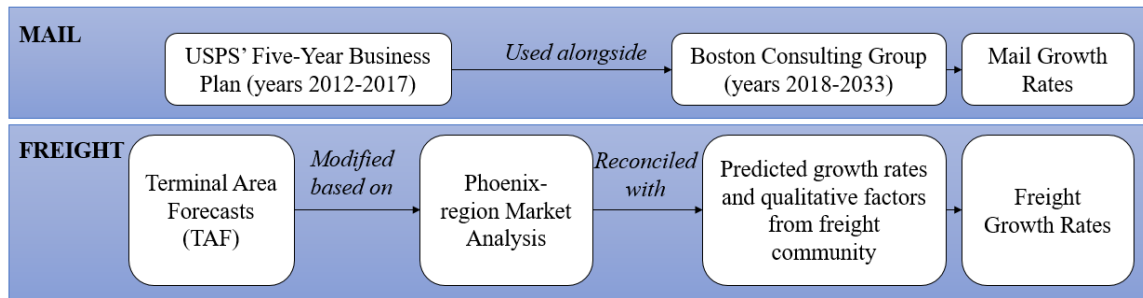
that e-retail may spur cargo growth, saying that “to the extent that the Phoenix region can facilitate growth of the online retail distribution sector, they will also likely aid growth of air cargo activity in the region” (PHX cargo study, p. 118).

#### 7.2.10.2 Forecasting

The PHX cargo study’s forecasting approach is unique because it very explicitly accounts for e-fulfillment by basing its cargo growth rates in the near term on estimates from freight community members. Planners qualitatively account for e-fulfillment in freight forecasts, but not mail forecasts. Mail and freight are modeled separately since mail generates much less volume and is subject to different dynamics (PHX cargo study, p. 124). Air mail at PHX was forecast by applying USPS’s Five-Year Business Plan to contemporary PHX mail volumes. USPS’s Five-Year Business Plan expects annual declines in mail volume of 2.8% from 2012 to 2017 (PHX cargo study, p. 129). For years 2018 to 2033, an annual change in mail volume from the Boston Consulting Group was adopted (1.5% annual decline).

To forecast freight, planners started with the growth rates from the FAA’s terminal area forecasts (TAF) (PHX cargo study, p. 126) and adjusted them based on the previously completed market analysis. Planners adjusted growth rates based on qualitative factors that air cargo stakeholders described in interviews (PHX cargo study, p. 127). E-fulfillment is one of the drivers of growth in the near-term [“Specifically, air freight for Integrator Operations was expected to grow somewhat faster in the initial five years of the forecast which reflects anticipated further growth by the online retail shippers as well as a new Intel

fabrication plant which will come on-line in 2014”] (PHX cargo study, p. 127). Figure 52 depicts the forecasting approach.



**Figure 52. PHX cargo study's forecasting approaches for mail and freight.**

**Source: Created by author based on PHX cargo study.**

#### 7.2.10.3 Freight Community Involvement

E-fulfillment is also incorporated via interviews with e-retail shippers and companies serving e-retailers (e.g., carriers, real estate brokers). Interviewees include e-retailers, high-tech manufacturers, aerospace companies, and biomedical firms (PHX cargo study, p. 79). Shippers make up a quarter of interviewees. Amazon’s participation was solicited, but none of the detailed notes in Appendix F reflect Amazon’s perspective, indicating that its participation was minimal at best (PHX cargo study, p. 80). Other interviewees discussed e-fulfillment at length. Interviews with air carriers reveal that e-fulfillment has been the main driver of air cargo growth in the Phoenix area, with e-retailers such as Amazon and Macy’s leading the activity. Integrators emphasize Amazon’s importance because of its size and growth rates, saying that the airport’s future cargo volumes will heavily depend on Amazon’s logistics network. In their words, “it all depends on Amazon” (PHX cargo study, Appendix F, p. 31).

Real estate brokers also raised the topic of e-fulfillment's large influence on land markets, mentioning specifically Amazon, Dick's Sporting Goods, and Macy's. Amazon appears to have committed to a medium-to-long-term presence since its facilities have 10-year leases, and it has invested to improve them (PHX cargo study, Appendix F, p. 37). Real estate brokers cite Arizona's lower costs (e.g., labor, rents, etc.) compared with California as a reason for e-fulfillment's growth (PHX cargo study, Appendix F, p. 35).

Planners also distributed a survey to shippers in the region in both the U.S. and Mexico (PHX cargo study, Appendix G and Appendix H respectively). The response rate for the U.S. survey was between 2% and 3%, with 20 surveys fully completed and eight partially completed. The surveys give insights about how, what, and where they ship (PHX cargo study, p. 80).

#### 7.2.10.4 Investments and Policies

Planners apply utilization rates to forecasted cargo volume to estimate airport infrastructure requirements (PHX cargo study, p. 170). Additional warehouse space is likely to be needed starting in 2023. Current cargo infrastructure is analyzed, and scenarios for changes to accommodate volume are created (PHX cargo study, p. 171). Planners also analyze aircraft ramp space and employee parking requirements (PHX cargo study, p. 170).

#### 7.2.10.5 Land Development

The PHX cargo study does not address land development around the airport. It focuses on direct aviation functions on airport property.

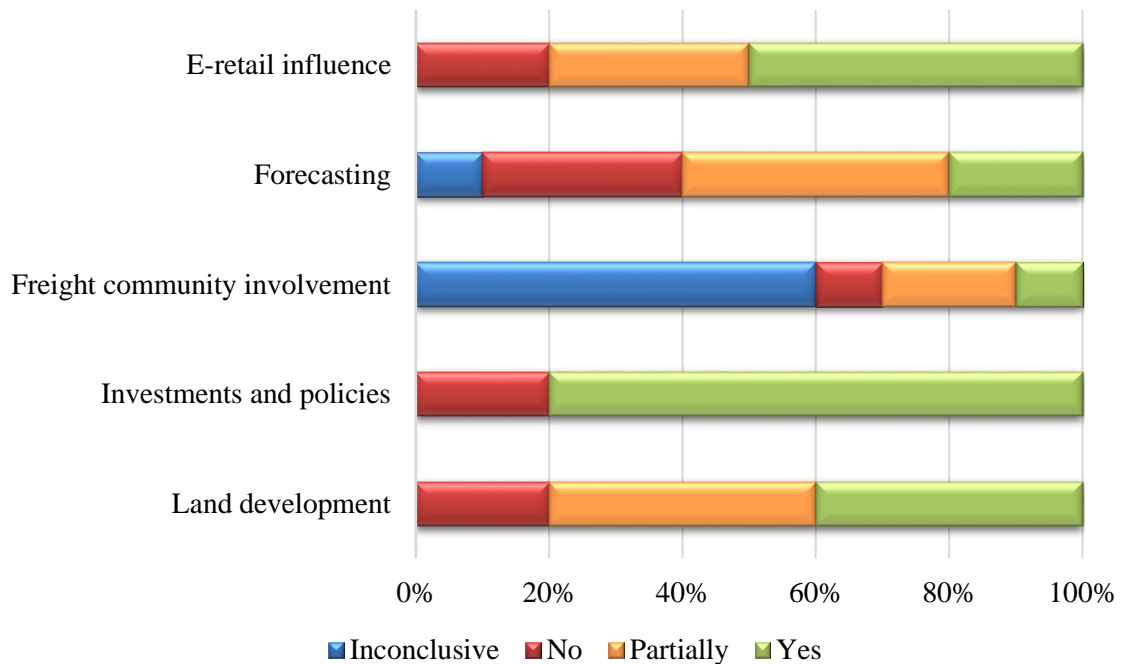
#### 7.2.10.6 Conclusion

The PHX cargo study contextualizes forecasting with an uncommon amount of freight community involvement around e-fulfillment, which is likely to capture the direction and rough quantity of near-term trends quite well. Planners approach e-fulfillment from the desire to accommodate cargo demand.

#### 7.2.11 *Document Review Results*

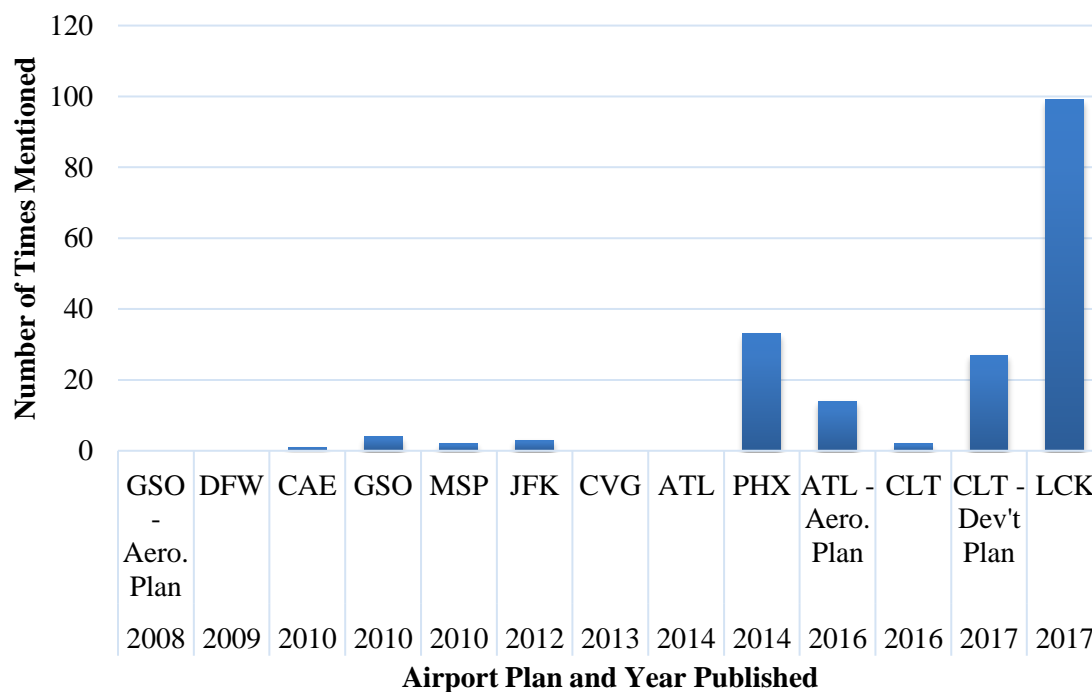
All reviewed airport plans conduct the core function of evaluating passenger infrastructure's adequacy, and eight out of ten also evaluate cargo infrastructure's adequacy. On other topics, there is much less uniformity. About half of airport plans name e-fulfillment as an influence on cargo, and another three plans focus heavily on integrator needs. By contrast, forecasting rarely accounts for e-fulfillment explicitly, although four out of ten plans reviewed employ growth rates or scenarios that are adaptable for e-fulfillment. The only plans that explicitly include e-fulfillment in forecasts are the PHX cargo study (for which planners used interviews about e-fulfillment to calibrate growth rates) and the LCK plan (for which planners quantitatively analyzed e-fulfillment's effect on specific cargo-generating activities). Freight community involvement is limited. The plans with the greatest freight community involvement are dedicated cargo studies. Finally, most plans study the airport's role in land development and seek to accommodate logistics land development either on or off airport, of which three target e-fulfillment by name. The frequency of each rating is summarized in Figure 53.

### Does Component of Plan or Study Consider E-Fulfillment?



**Figure 53. Summary of the results of document reviews.**

The most recent plans and studies address e-retail most comprehensively. Almost none of the plans published before 2014 address e-retail or related terms by name (e.g., e-commerce, online retailers, Amazon), with some exceptions such as JFK International Airport. By contrast, nearly all plans published from 2014 onward evaluate e-retail cargo with increasing levels of sophistication. These include two Aerotropolis plans (ATL and CLT) seeking to develop land around the airport for e-fulfillment, and the LCK plan, which considers the phenomena with the most detail, citing terms related to e-retail 99 times in just the first three chapters of the document (the later chapters are not published as of November 2017). If this holds true, e-retail will become a mainstay of airport cargo planning.



**Figure 54. Number of times e-retail or related term is cited in the plan or study.**

**Note: Related terms include ‘e-retail,’ ‘e-commerce,’ ‘Amazon,’ ‘online retail’**

### 7.3 Interviews

Amazon Prime Air is a brand for three carriers with separate air operator’s certificates serving Amazon, namely ABX, ATI, and Atlas. Airport staff interacts almost exclusively with these carriers rather than Amazon. The remainder of the dissertation refers to Prime Air instead of the three carriers, a designation which refers to one or more of the carriers operating on behalf of Amazon.

Staff at airports where Amazon Prime Air has a presence were contacted for interviews. Staff at seven airports agreed to discussions, generally by phone and in one case via email. Interviews with two airport consultants and a passenger airline air cargo

director were concurrently analyzed. Airports, organizations, and staff members remain anonymous in the report. Most interviewees work in air service development, and some specialize in planning, operations, or real estate development. The interviews were analyzed by coding interview transcripts, detailed notes, and / or post-interview memos. Codes are based on a combination of theory and ground-up emergence during interviews.

The information obtained in the interviews is divided into four sections, mirroring the five sections of the document reviews. The first section is “e-fulfillment influence,” which assesses the trajectory of e-retail cargo growth at the airport. The second section is “forecasting,” and it speaks to staff’s ability to predict e-retail cargo needs. The third section is “investments and policies.” This theme addresses concrete actions to accommodate e-retail cargo, both in the short term and the long term. The fourth and final section is “land development,” and it refers to means for airports to encourage aeronautical-related activities around cargo and e-commerce on or near airport property. These sections omit freight community involvement, which is subsumed into “investments and policies.”

### *7.3.1 E-fulfillment Influence*

#### *7.3.1.1 E-retail Air Cargo Volumes*

E-fulfillment has not dramatically changed the geography of air cargo among airports, with traditional gateways like New York (JFK), Los Angeles (LAX), Chicago (ORD), and Miami (MIA) maintaining their central positions in cargo networks. Yet, cargo is growing quickly at many airports. At one airport, Prime Air’s arrival corresponded with exceptionally fast cargo growth of nearly 30% year over year. Another interviewee described airport cargo activity as firing on all cylinders with “rapid growth really

anywhere you look” related to the region’s overall economic trajectory. Integrators have consolidated, and DHL ended its domestic air network, leading DHL to forfeit ramp and warehouse space at several airports. Otherwise, integrators’ activity exhibits steady continuity without major trends upwards or downwards. As one interviewee described, before Prime Air came to the airport, Amazon used FedEx and UPS heavily, and now the airport has “Prime Air flights in addition to [Amazon’s] continued use of the other cargo operators.”

E-retail has increased international cargo at some airports, especially regarding exports to Asia. Interviewees at two of the seven airports describe e-fulfillment exports generated by consumers, primarily in Asia, ordering from U.S. e-retailers. Businesses consolidate these customers’ purchases at a U.S. address and ship them by air at lower bulk rates to their country of residence. Final delivery occurs through domestic postal systems. Some large aggregators have established warehouses near gateway airports. Interviewees said that state sales tax laws had played a role in determining which gateways the aggregators would use. States with low sales tax have an advantage since shipments to an in-state aggregator do not pay sales tax. However, an interviewee also pointed out that sales tax is not due on items for export to overseas consumers if the shipments are correctly documented.

#### 7.3.1.2 Factors Affecting E-retail Air Cargo Volumes

Interviewees uniformly credit Prime Air for much of their cargo growth. Interviewees believe that Prime Air makes shipments from FCs near the airport, serves customers in the airport region, and / or rebalances inventory among its FCs. Therefore,



Prime Air selects a region to serve based on internal operations and only then considers candidate airports. Below are the factors that interviewees believe may have led Prime Air to select their airport over others in the region.

### **Airport's Responsiveness and Flexibility**

Many interviewees describe Prime Air's decision-making process and commencement of operations as extremely fast, one in which mere days are available to arrange tours and find space that would meet the carrier's needs. One staff member describes it as "the fastest process...ever seen at the airport." This speed requires airport staff to be extremely proactive and responsive.

### **Availability of Space for Operations**

Each airport is in a unique situation regarding its ramp and building space. Staff at three airports indicate having ample space available for medium-term cargo growth. Several airport staffs accommodated Prime Air in building or ramp space previously made available due to integrator consolidation. Staff at one airport is already expanding ramp area to accommodate Prime Air's projected growth.

### **Regional Cargo Ecosystem**

Interviewees representing three airports indicate that an existing cargo ecosystem is useful in meeting new carriers' needs on and off the airport. Many large cargo airports already have a well-developed cargo ecosystem. In at least one case, the airport staff played a role in strengthening the ecosystem for Prime Air's operations. Ways to strengthen the

ecosystem include assistance in training and badging airside employees, and partnering with local technical colleges for aviation- and logistics-related training programs.

### **Proximity to Existing Fulfillment Centers**

Amazon FCs in the same metropolitan region predate Prime Air service for at least six of the seven airports. Some FCs are within a few miles of the airport, and others are farther away in the same region. Interviewees credited these facilities' presence with raising their region's attractiveness to Prime Air.

### **Proximity to Large Customer Base**

Interviewees representing at least three airports credit a large regional customer base with helping to attract Prime Air. Proximity to customers within the region differentiates airports that Prime Air selected from other candidate airports.

### **Insignificant Factors**

None of the interviewees described monetary incentives as a factor in Prime Air's arrival. When asked about incentives, one interviewee said that new carriers are much more concerned with the service's ability to function than with marginal cost savings. In other words, serving the right airport at regular price is preferable to serving the wrong airport at a discount. Inquiries to staff at another airport revealed that Prime Air did not seek out monetary incentives. Nonetheless, in-kind incentives (e.g., reduced rate office space) may help Prime Air begin operations in some cases.

### 7.3.2 *Forecasting*

The interviews suggest several major difficulties with forecasting e-retail air cargo. The greatest difficulty by far is a lack of data. Disaggregated cargo data by sales channel is unavailable even though it would facilitate forecasting. One interviewee said that available data aggregates “all sorts of heterogeneous consumer products,” making it hard to extract information about e-fulfillment, while another said regarding international e-retail export volumes that they “don't have anything to back [their estimates] up” with. Moreover, data are reported at the carrier level, which complicates analysis of carriers that serve multiple companies (such as ABX serving both Prime Air and DHL). Some airport planners use interviews to understand e-fulfillment activity at the airport. An interviewee referenced anecdotes and relationships with the freight community that help staff understand international e-retail shipments. Another interviewee is building relationships with e-retail aggregators in hopes of gaining insights on growth trends and shipment patterns. E-retailers also hesitate to share information with airport staff. An interviewee said that “most companies are not willing to share their growth plans in the written form, or in meetings with others.” Another interviewee reported “lov[ing] nothing more than to have somebody from Amazon come in and give us a high-level overview of the business model,” but that Amazon has not been willing.

Airport leaders normally pay little attention to cargo compared with passenger activity, which may partially explain the data's inadequacy. As an air cargo consultant stated, “most U.S. airports pay very little attention to cargo, so e-commerce trends don't register either.” Airports' operating model encourages them to privilege passenger activity over cargo activity. Most airport corporations build and operate passenger terminals in-

house and obtain most of their revenue from passenger activity. By contrast, they normally lease land to cargo operators and raise minor revenue through it. Airport authorities' relationship with cargo activity has traditionally been that of a somewhat distant landlord rather than an operations manager. This attitude markedly contrasts with airports overseas, particularly in major Asian hubs, where cargo receives much more attention.

With limited data, staff have adopted several approaches to forecasting data. One approach is to predict carriers' short-term needs based on a variety of non-definitive signs. Sometimes airport staff observe signs of growth before operations expand, for example through a ground handling company that hires employees before a carrier adds flights. Another interviewee examines carriers' aircraft orders, warehouse leases, and job hiring announcements. Carriers are sometimes "willing to discuss future needs of the airport, which give[s] [staff] a better clue of what they might be doing." Shippers and carriers are more hesitant to explain the evolution of their operations than to describe their future aviation needs in general. Indirect methods of obtaining information can provide short- to medium-term insights about an e-retailers' likely operational trajectory. Another approach to understanding e-commerce trends rests with carriers and freight forwarders. An airport interviewee suggested that carriers and freight forwarders possess detailed information about the goods that they are transporting or shipping respectively. The data might provide a better picture even though most airports do not have access to it.

### 7.3.3 *Investments and Policies*

Investments and policies related to e-fulfillment are composed of tactical actions and long-term planning. Tactical actions remedy an immediate situation, while long-term planning proposes investments and policies to remain competitive.

#### 7.3.3.1 Tactical Actions

Staff at several airports have undertaken construction or reallocation of airside building and ramp space to accommodate Prime Air's activity over the medium-term. An interviewee expects Prime Air to request additional ramp and building space, and has explored relocating other functions to accommodate Prime Air's growth. Staff at two other airports are already expanding cargo ramps and repurposing buildings.

#### 7.3.3.2 Long-term Planning

An interviewee addressed the inadequacies of airport planning to address fast-moving trends. There is "an inherent conflict" between airport staff's needs to make immediate decisions, and leaders' desire to comprehensively optimize facilities. A long planning process leaves staff bereft of interim guidance. According to staff at another airport, many changes in the airport's operations and trajectory arise were not foreseeable when the last master plan was completed. Therefore, the airport staff has learned to remain attentive to trends that might affect airport operations and conduct mini-studies or analyses to fill the gaps in the plan.

Prime Air consistently took the first step in contacting airport staff. None of the airport staffs recruited Prime Air. As one interviewee said, "sometimes you're out pitching

to airlines and trying to obtain service,” but this is not how it worked with Prime Air. The airline contacted the airports with a proposal of service. Space to accommodate Prime Air was not preplanned either. Four interviewees allocated space to Prime Air that had been liberated when another airline ceased operations or relinquished its facilities. The decision to vacate the facilities, which ultimately opened them to Prime Air, depended on those carriers, not on the airport. One interviewee highlighted that “sometimes good planning needs luck involved with it.”

#### 7.3.3.3 Proactive Assistance for Air Cargo Development

An interviewee proposed a way for airport staff to help passenger carriers solve the challenges that impede their competitiveness in e-retail cargo markets. Passenger airlines are required to follow stricter standards than cargo airlines for hazardous goods transported in bellyhold space. Passenger airlines can only accept goods from shippers that are registered with the Transportation Security Administration (TSA) under ‘known shipper’ provisions. To assist cargo transport in bellyhold space, airport staff can develop ‘facilitation centers.’ These centers assemble shipments for air transport aboard passenger airlines, electronically pre-clear international shipments, screen items from unknown shippers, and register themselves as a known shipper. The facilitation center is a very proactive way for staff to increase airports’ effective cargo capacity and connectivity by helping shippers use the bellyhold capacity that already exists. A proactive approach to air cargo could also help the airports become centers for coordinating and executing new technologies, such as short- and medium-range aerial cargo drones.

#### *7.3.4 Land Development*

Staff at three of the seven airports cited published plans for developing land for aviation-related uses including cargo functions. In one case, airport planners are preserving the land for eventual aeronautical activity, and in the other two cases the airport planners are seeking airport-related development, including e-fulfillment. Implementation plans have begun at both airports. Staff at one airport is rezoning near-airport land to prepare it for logistics and industrial activity (previously zoned residential). Staff will sell the sites after rezoning is complete. Staff at a second airport is also selling some of its near-airport parcels for cargo-generating uses.

#### **7.4 Conclusions from Airport Planning Benchmarking**

Airport planners are adapting to a fast-changing e-fulfillment cargo industry. E-fulfillment manifests differently at major international gateways, integrator air hubs, medium-size, and smaller airports. Many airport staff have begun to consider e-fulfillment as a revenue generator, which has spurred planners and air service developers to pay attention to it. Obtaining data about e-fulfillment has been a consistent challenge. Airport planners have overcome meager data with two principal approaches. The qualitative approach involves interviews with the freight community. The second approach is quantitative. The quantitative approach is difficult because of the lack of data on e-retail cargo. Obtaining better data on a large scale requires changes in carriers' data reporting. In the shorter term, micro-scale activity analysis can produce reasonable forecasts.

Nonetheless, accuracy of long-term forecasts is low because of fast-changing cargo-generating activities. Airport staffs are adapting to uncertainty with short- and

medium-term strategies to open or renovate existing facilities when demand might soon exceed capacity. Master planning processes should be streamlined so staff can soon benefit from up-to-date guidance.



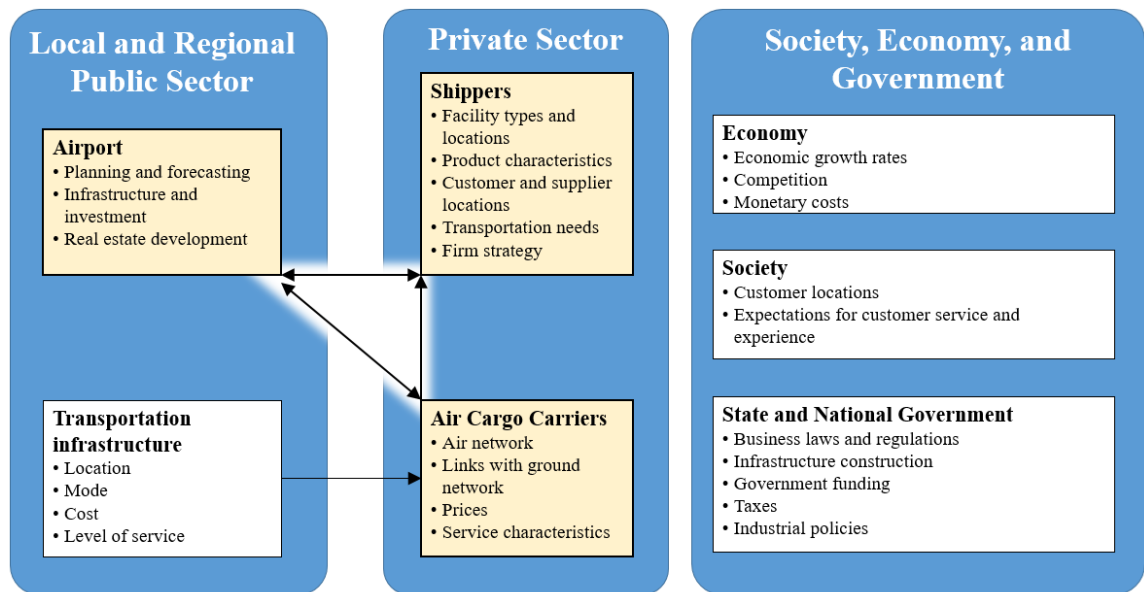
## **CHAPTER 8. INTEGRATED ANALYSIS**

### **8.1 Introduction**

Results from the analyses are synthesized and overlaid on the conceptual model in this chapter. This allows for updating the conceptual model in three steps: (1) presenting the original conceptual model, (2) identifying factors influencing DC location and factors influencing FC location, and (3) mapping airports' consideration of e-fulfillment in their capital plans. The dissertation's contribution to urban planning (as distinguished from airport planning) is further developed in this chapter. Estimates are provided of the scale, timeframe, and location of impacts on transportation and economic development issues important to urban planners.

### **8.2 Conceptual Model**

Airports, carriers, and shippers are tightly interconnected in a web of influence and interdependence. Shippers seek freight transportation for the delivery of goods to stores or customers, thereby generating demand around which carriers build their networks. The carriers' in turn use airports' facilities and ground transportation to support aircraft and other vehicle movements, generating cargo activity at airports. Airport staffs may appeal to air cargo carriers with facility updates, monetary incentives, fee reductions, or other offers that facilitate carriers' profitability. Airports, carriers, and shippers each operate within macro-scale economic, social, and governmental conditions. These factors are displayed in the theoretical concept model in Figure 4.



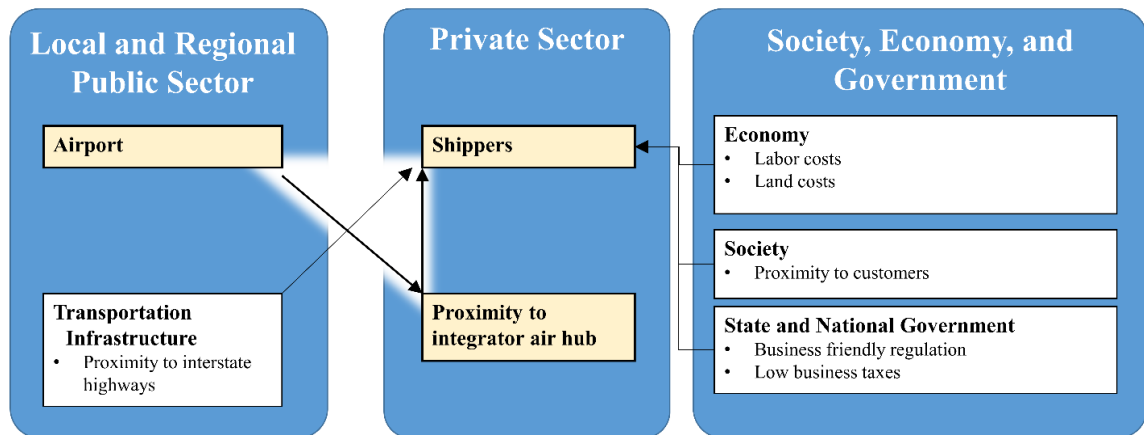
**Figure 55. Conceptual framework with primary actors highlighted.**

Airport planners forecast shipper demand and air carrier operations based on one of several forecasting approaches and supporting data. Some forecasting techniques extrapolate demand based purely on trends, while others concentrate on the phenomena that drive carriers' business activity. Forecasting is very uncertain because carriers' networks and demand for their services are not fully predictable by any set of variables, and forecasts of the underlying conditions are also error-prone. Accordingly, planners sometimes involve users or the broad freight community in the airport planning process to fortify the trends and assumptions used in forecasting.

The results of the location model and shipper survey are combined to compare theory-based expectations with observed factors, and to identify differences by sales channel. By and large, DC managers most highly value the ability to cheaply reach their stores via nearby highways. They also prize low land costs, low taxes, and minimal regulations even if the location model's results emphasize that other traits sometimes

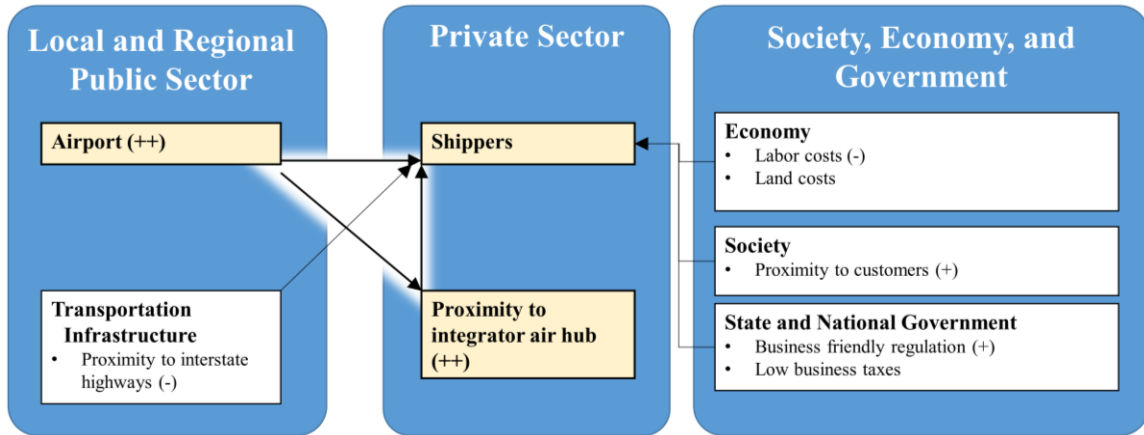
outweigh these traits in their final location choice. Some DCs operate in ways that make proximity to an integrator's air hub useful, but most do not. Even if DCs do often locate near integrator air hubs, it may be to take advantage of the logistics resources and developed ground transportation networks in these regions rather than to use integrators' air networks. DC managers do not report valuing proximity to airports or integrators' air hubs, nor do they report frequently using air for outbound shipments. Even when DCs do locate near integrator air hubs, the reasons for that location likely derive from other factors.

The analysis leaves some factors' roles more ambiguous. State business environment is an example. DC managers report valuing business-friendly environments in the survey, but the location model reveals that many locate in relatively unfriendly states. These results may be reconciled by distinguishing between stated preference and revealed preference. In revealed preference, any factor may be outweighed by other factors deemed more important. When the results of the location model and shipper survey diverge, the shipper survey has better causal reliability regarding shippers' preferences, while the location model provides a better foundation for understanding tradeoffs in decisions. Figure 56 updates the conceptual model for DCs based on analysis results, showing the economic, social, and government-related factors that have been found to influence DC location.



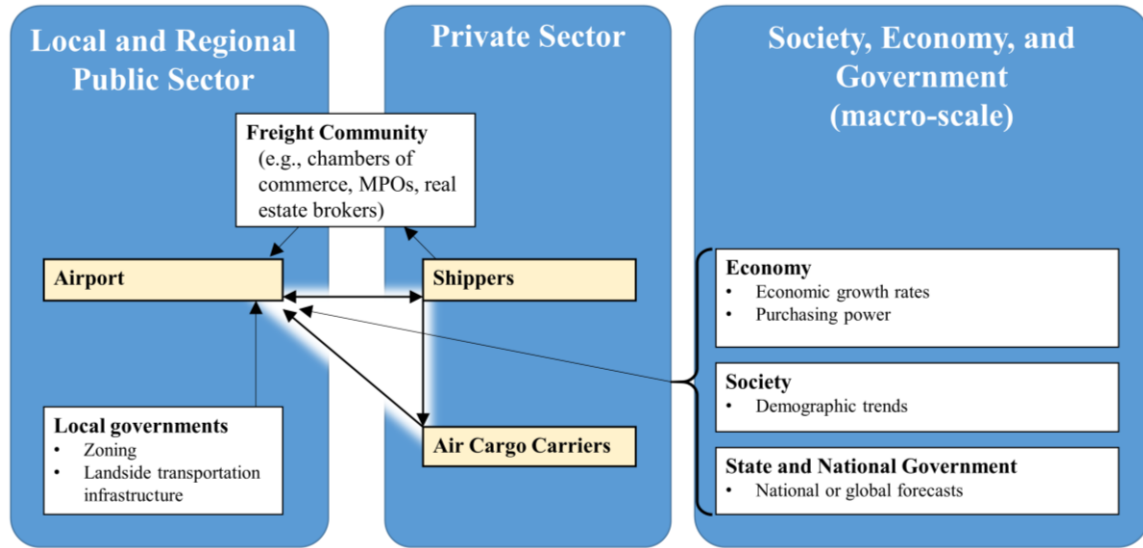
**Figure 56. Influences on DC location and operations.**

Figure 57 maps the factors that influence FC location, indicating in parentheses factors' strength compared with their strength in the DC concept map (for instance, '+' means 'more important,' and '++' means 'much more important'). FC managers value proximity to integrators' air hubs much more than DC managers, and this finding is supported by the literature, the location model, and the shipper survey. FC managers also value customer proximity and business-friendly environments more than DC managers. Both the shipper survey and location model note that FCs gravitate towards business-friendly states, which may have also historically been states that allowed e-retailers to avoid or minimize sales tax payments. By contrast, FC managers place less importance on labor costs in the shipper survey, although the location model still finds low labor costs to associate with airports' FC access. FC managers value low land costs less than DC managers, while highway access is equally prized by firms of both sales channels.



**Figure 57. Influences on FC location and operations compared with DCs.**

Beliefs about e-fulfillment, and choice of data and methods are remarkably varied in airport plans. Therefore, Figure 58 traces the breadth factors considered in airport plans rather than a single archetype. Airport planners may draw from a wide array of information to understand the nature of air cargo demand. Some planners supplement quantitative models with qualitative inputs from the freight community, notably carriers. Shippers are sometimes interviewed, but they hesitate to reveal their operations. The freight community includes organizations like chambers of commerce, economic development planners, and real estate brokers. The broader freight community comprised of developers, brokers, and related organizations shares information more readily than shippers or carriers, but is more distant from e-fulfillment decision making. To describe only the relationship between airports and shippers, a few airports attempt to attract shippers and create a long-term demand for air cargo by providing industrial land near the airport.



**Figure 58. Influences on air cargo planning for e-fulfillment.**

### 8.3 Responses to Research Questions

The research questions and hypotheses are reiterated in sequence, and answers are provided in the paragraphs following each research question.

**Q<sub>1</sub>** What airport and air cargo carrier traits are associated with e-fulfillment?

**H<sub>0</sub>:** Airports with greater air cargo connectivity are *not* associated with greater FC access compared with DC access.

**H<sub>1.1</sub>:** Airports with greater air cargo connectivity are associated with greater FC access compared with DC access.

The location model allows for the null hypothesis  $H_0$  to be partially rejected. Integrator air hubs are most closely associated with e-fulfillment activity. The shipper survey addresses the drivers of differences between FC and DC access, namely FCs' strong tendency to transport shipments via integrators and the postal service. Similarly, the

location model shows that regions accessible to more people at a short-to-moderate distance attract e-fulfillment activity and B&M retail logistics activity. Therefore, alternate hypothesis  $H_{1.1}$  is accepted.

The location model does not support the hypothesized variable of air connectivity independently of hub status. Paradoxically, international passenger destinations have a negative relationship with DC access and no association with FC access, meaning that it is the presence of an integrator air hub more than air cargo connectivity independent of hub status that is associated with e-fulfillment.

**Q2** What dynamics might explain differences in FC and DC location?

**H<sub>0</sub>:** FC and DC managers assign identical importance to multiple regional, airport, air system, and ground transportation traits.

**H<sub>2.1</sub>:** FC managers rate airports and airport traits as more important than DC managers.

**H<sub>2.2</sub>:** FCs use air cargo for outbound transportation more frequently than DCs.

**H<sub>2.3</sub>:** FCs use integrators and USPS for outbound transportation more frequently than DCs.

The null hypothesis  $H_0$  is rejected and each alternate hypothesis retained. FC managers rate airport proximity to be much more important than DC managers. In fact, the greatest difference in importance between the sales channels exists for airport proximity. Although not statistically significant, FC managers also report greater importance for 24-hour airport operations and competition among carriers at an airport.

H<sub>2.2</sub> is also accepted since FCs often use air transport for outbound shipments, whereas almost no DCs use air transport for outbound shipments. When DCs do use air transport, it is often because of unique circumstances, such as shipments to stores in Hawaii. By contrast, DCs prefer truckload (TL) shipments.

H<sub>2.3</sub> is accepted since FCs use integrators and USPS for outbound shipments much more frequently than DCs. FCs likely prefer these carriers because of their small shipment sizes and need to deliver to the customer's door. By contrast, DCs prefer other third-party logistics companies (3PLs), which often provide truckload shipments.

The rejection of the null hypothesis confirms that differences in the form of e-fulfillment and B&M retail logistics networks. It also lends support to the finding that FCs locate near airports to access air cargo and integrator ground networks. Locating near an airport and integrator air hub allows FCs to make deliveries faster, more cheaply, and more reliably, while also extending their working day.

**Q<sub>3</sub>** How are airport planners preparing for e-retail cargo?

<p><b>H<sub>0</sub>:</b> Airport planners are not planning for e-fulfillment.</p>
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The null hypothesis H<sub>0</sub> is rejected. Early evidence supports the proposition that more recent airport plans address e-fulfillment much more thoroughly than older plans. Additionally, staff at airports served by Prime Air are paying close attention to e-retail logistics. The interviews and planning documents suggest that a large logistics cluster is not necessary for e-fulfillment to have a high profile at the airport. The presence of Prime Air or the activity of a moderate number of domestic e-retailers or international e-



fulfillment shipments are sufficient to raise e-fulfillment's profile in the airport staff's consciousness. The analysis provides additional details on airport staff's analysis of and planning for e-fulfillment.

## **8.4 Implications for Regional Development**

Impacts of e-fulfillment growth on regional development are forecast in the following sections by extrapolating e-retail market penetration. Multipliers are applied to estimate e-fulfillment's need for land and workers. The relative importance of regional traits to FCs' and DCs' operations allows for estimates of regions' suitability for e-fulfillment and B&M retail logistics.

### *8.4.1 Suitable Regions*

Regional development impacts are geographically concentrated according to regions' suitability for e-fulfillment activities. As the shipper survey and interviews revealed, most of the regional traits that appeal to FCs also appeal to DCs, with only a few traits such as proximity to integrator air hubs diverging dramatically between the two. The mean importance assigned to each trait differs. Consequently, a discussion of regional development should begin by estimating regions' suitability for e-fulfillment and for B&M retail logistics. Suitability is estimated by assigning an importance weighting to each variable measured in the survey according to the sales channel's mean importance. The variables are estimated as shown in Table 22 below, which also displays the importance weightings assigned to each sales channel.

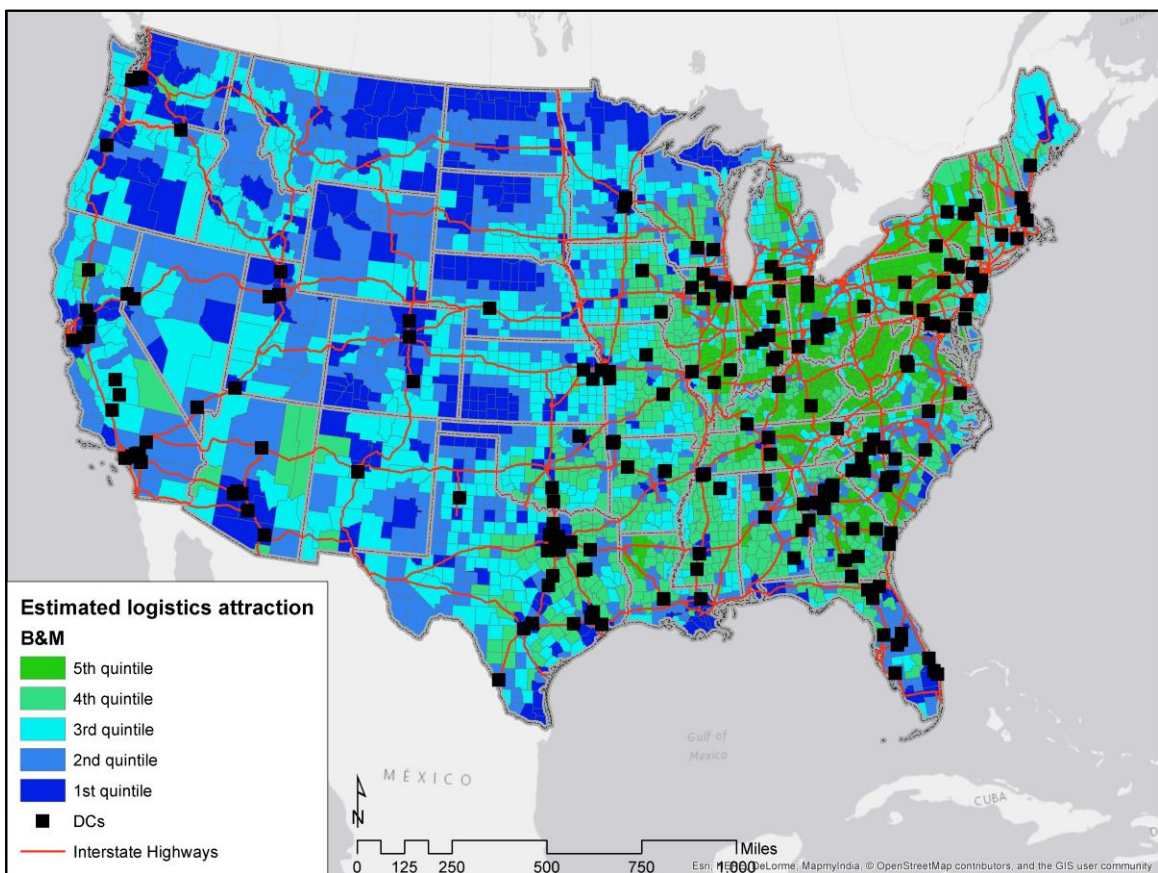
**Table 22. Variables to estimate counties' logistics suitability.**

<b>Theoretical variable</b>	<b>Operational variable</b>	<b>Source</b>	<b>FC weight</b>	<b>DC weight</b>
Labor costs	Median salary for high-school graduates	U.S. Census Bureau, American Community Survey 2011-2015	1.4	2.2
Land costs	Inverse population density (based on correlations between land value and population density) (Geological Survey 1972; Evans 1973)	U.S. Census Bureau, American Community Survey 2011-2015	1.7	1.8
Business taxes and business friendly regulation (combined)	Business environment ratings	Thumbtack (2015)	1.9	1.8
Proximity to airport with cargo service	$Airport\ access = \sum_{i \in I} \frac{cargo_i}{\sqrt{dist_i}}$ <p>where <i>cargo</i> is the airport's 2015 cargo volume in tons, <i>dist</i> is the Euclidean distance in kilometers to the airport centroid, and <i>i</i> is a given airport from the whole set <i>I</i>.</p>	Calculated	2.0	0.4
Proximity to Interstate Highway	Distance to nearest highway (km)	Calculated	1.7	2.5
Low roadway congestion	Highest travel time index (TTI) fully or partially overlapping with county	Texas A&M Transportation Institute (2015)	1.0	1.5
Proximity to seaport with cargo service	Distance to nearest seaport (km)	Calculated	0.9	0.9
Ability to use freight rail	Proximity to intermodal terminal	Calculated	0.7	1.0
Proximity to suppliers	Omitted because supplier locations cannot be determined	na	1.0	1.4
Proximity to customers	Population within 399 km radius (overnight driving distance) of county centroid	Calculated	2.7	2.0

**Note: 'na' signifies 'not applicable.'**

Based on these estimates, the counties that are most suitable for B&M retail logistics are identified in Figure 59 (most suitable in dark green, least suitable in dark blue).

The most suitable counties are generally in the eastern portion of the United States since this is where population is most clustered. There is a moderate amount of variation within a given region as a function of estimated land value and congestion, with the most suitable locations tending towards the rural or small-town areas around major metropolitan areas. In the West, counties along Interstate Highways demonstrate moderate suitability for B&M retail logistics.

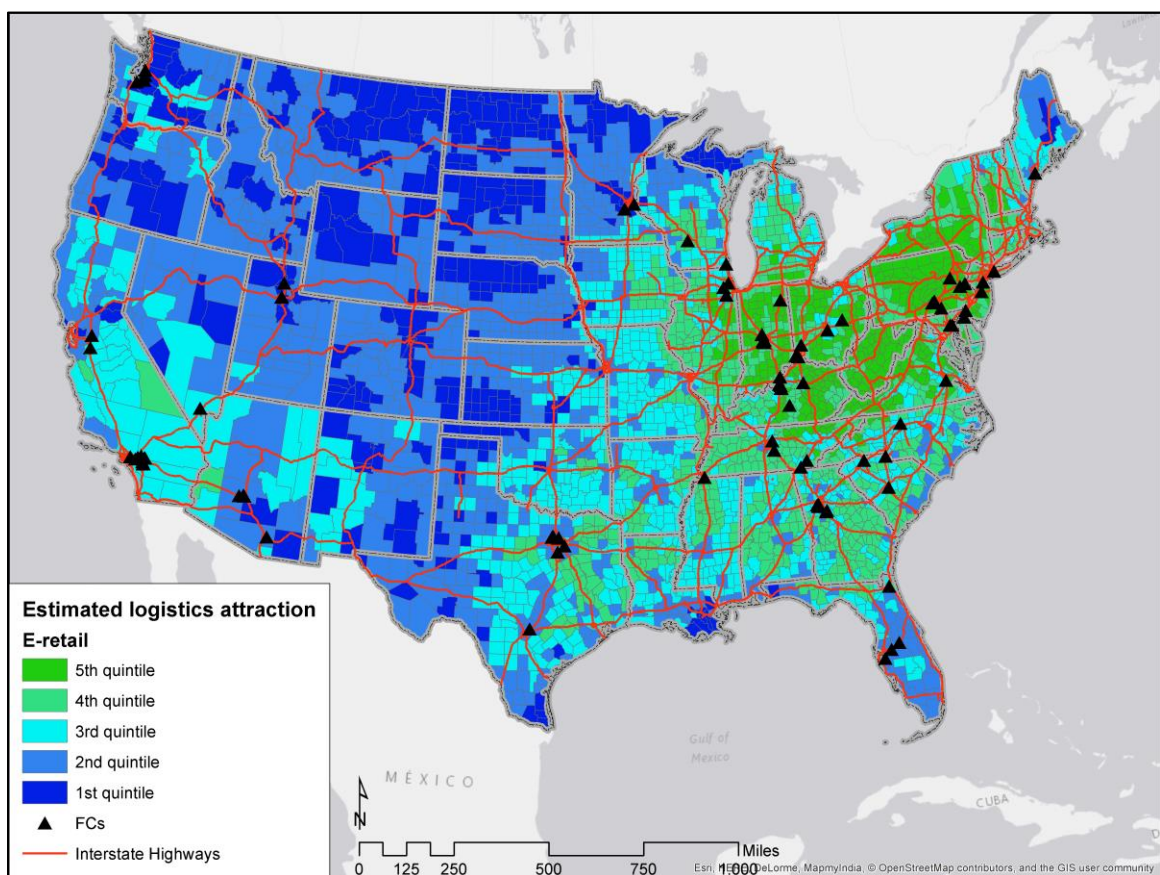


**Figure 59. Estimated B&M retail logistics suitability.**

**Green: higher suitability; blue: lower suitability.**

Conversely, counties of high suitability for e-fulfillment cluster in the eastern third of the country and to a lesser extent in California and Arizona, as shown in Figure 60. The

areas of highest suitability tightly center on a swath roughly within the triangle with vertices in Chicago, IL; Chattanooga, TN; and Hartford, CT. There are other clusters of relatively high suitability throughout the southeast, in eastern Texas, and in California. The least suitable areas are in the interior West, which is relatively isolated from groupings of large metropolitan areas. Factors' importance will continue to change as the industry matures.

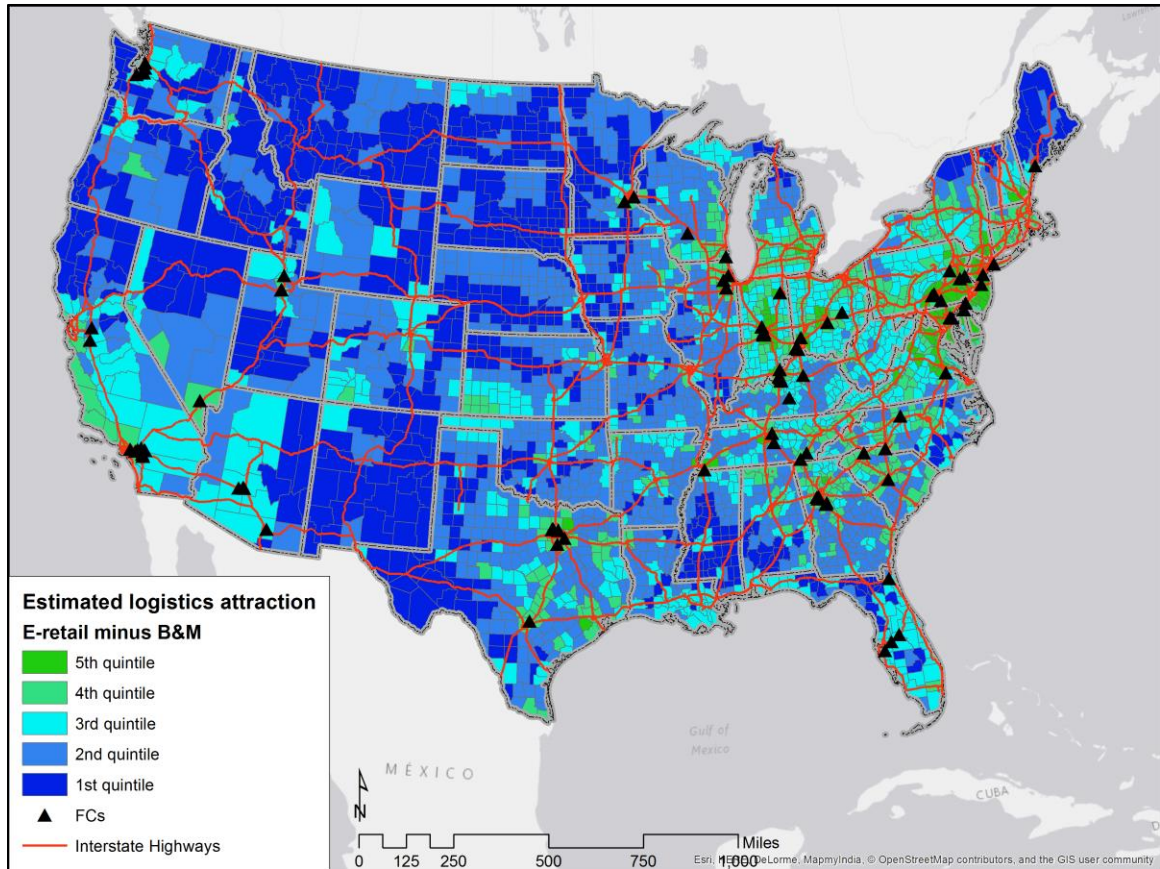


**Figure 60. Estimated e-fulfillment suitability.**

**Green: higher suitability; blue: lower suitability.**

FC managers' high valuation of population proximity is reflected in the difference between e-fulfillment suitability and B&M retail logistics suitability, shown in Figure 61.

Counties close to major metropolitan areas are becoming much more suitable for retail logistics as e-fulfillment expands. Some of the counties posting the biggest gains are concentrated between New York City and Washington DC; around the Midwestern logistics hubs of Columbus, Cincinnati, Louisville, Indianapolis and Chicago. In the Texas triangle area; and in California between Los Angeles and San Francisco. Most of these regions have in common proximity to large customer bases, proximity to major cargo airports, and centrality in the Interstate Highway network. As e-fulfillment grows, the employment, land use, and transportation impacts should concentrate in these ‘green’ regions in Figure 61.



**Figure 61. Increase in suitability from B&M retail logistics to e-fulfillment.**

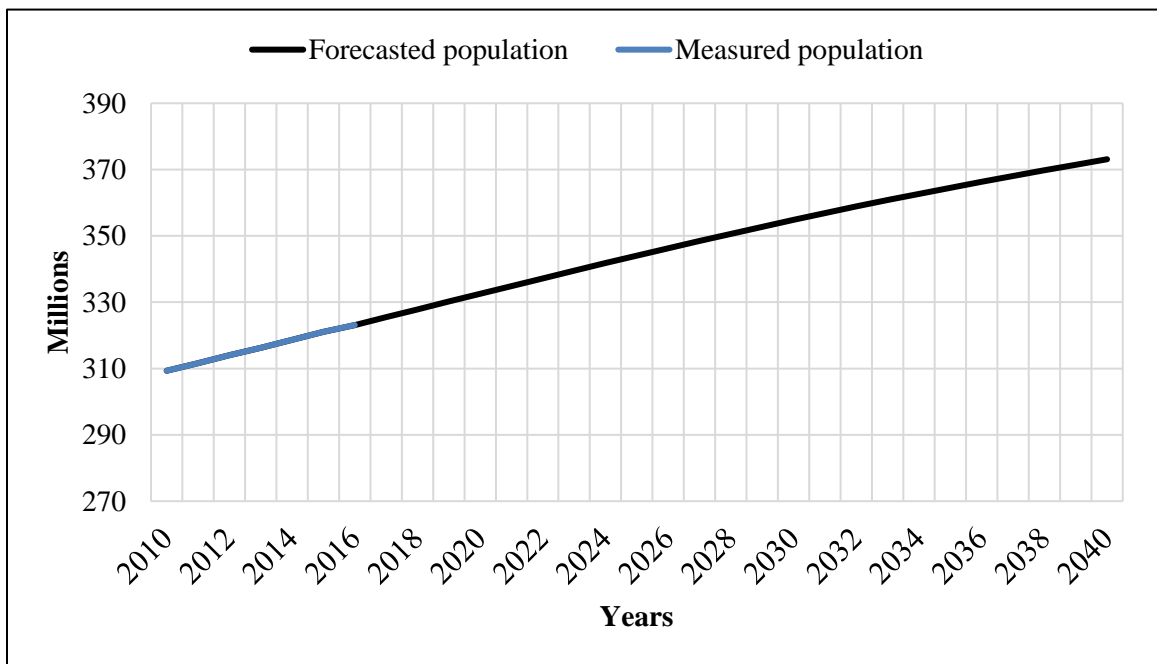
**Green: higher suitability; blue: lower suitability.**

#### 8.4.2 Growth of E-retail

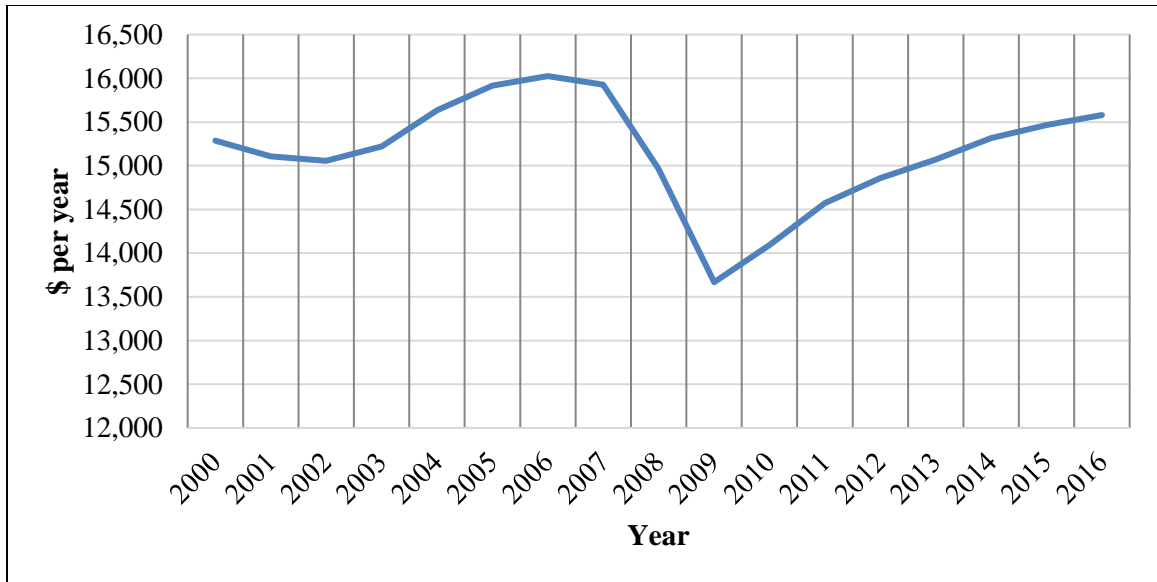
Before forecasting e-fulfillment impacts on land use or employment, it is first necessary to forecast e-retail sales volume. This is done via trend extrapolation of e-retail market share using a generalized linear model (GLM) with a quasi-binomial logit distribution and forecasting future retail sales volume by applying a ‘per capita sales’ multiplier to U.S. Census population forecasts. The two models’ outputs in each year are multiplied to estimate the size of the domestic e-retail market.



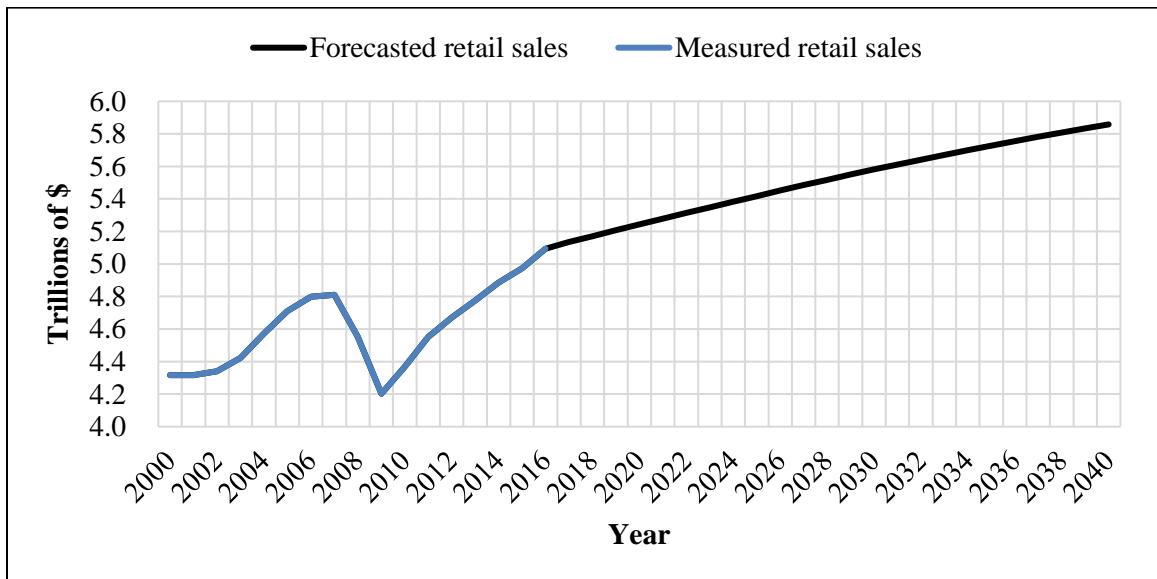
The U.S. Census Bureau's (2018) population projections through 2060 provide a baseline for projecting domestic retail sales. Population is expected to grow steadily over the planning horizon (Figure 62). A forecast of U.S. retail sales volume is obtained by multiplying the population in each future year by the per capita retail size, which has remained relatively steady around \$15,162 inflation-adjusted (2018) dollars since 2000. Per capita retail spending is displayed in Figure 63.



**Figure 62. Forecasted population for the United States.**



**Figure 63. Per capita retail spending (inflation adjusted to 2018).**



**Figure 64. Forecasted U.S. retail sales.**

E-retail market share is forecasted using a logit model calibrated with market share data from the U.S. Census Bureau (2016) between 1999 and 2016. This model produced the standard estimate of e-retail market share. The GLM model accepts the year as the independent variable and e-retail market share, and it produces a coefficient and intercept



that can be applied to the following logit model equation (Equation 1). Unlike regular logit models, a quasi-binomial logit model can accept continuous variables as dependent variables. A logit model is preferred because it allows for a maximum market share that cannot be exceeded.

$$y_i = \frac{e^{(\beta_0 + \beta_1 x_1)}}{1 + e^{(\beta_0 + \beta_1 x_1)}} \quad (\text{Equation 1})$$

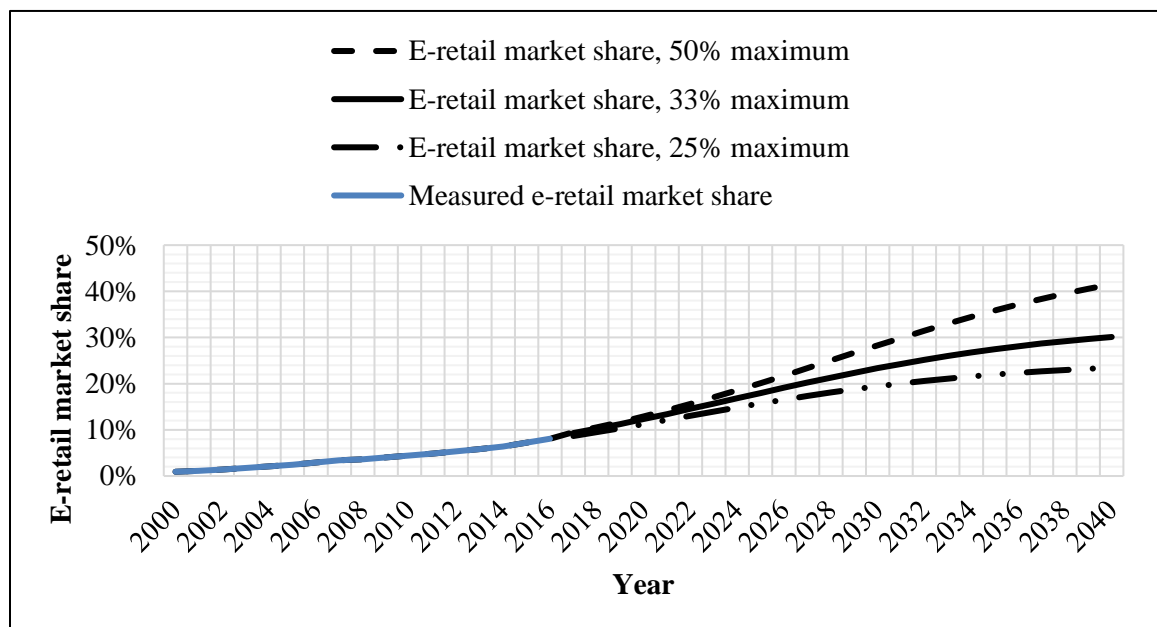
The unknown that inhibits market share forecasts is the long-term equilibrium between e-retail and B&M retail. As retail approaches equilibrium between the sales channels, e-retail market share will stabilize. No one knows what e-retail's equilibrium market share will be. For instance, in a widely quoted statement, the founder and president of FedEx, Fred Smith, asked the following (reported by Seeking Alpha (2017)).

“E-commerce is not going to eliminate the retailing sector of the country. It's about 10% now. It's certainly going to grow as a percentage. But will it be half? I doubt it. I think you're going to see e-tailers become more brick-and-mortar. And I think you're going to see brick-and-mortar become more e-tailers. You have to be flexible and nimble to be able to deal with the market as it evolves, because you're not going to be able to predict exactly how it's going to evolve, that I can promise you.”

By contrast, a senior executive at Cushman & Wakefield, one of the largest commercial real estate companies, recently suggested an equilibrium position for e-retail around half of overall market share (Morris 2017b). Therefore, three scenarios are created with three different equilibrium market shares for e-retail: one quarter, one third, and half

thirds (called the “25% maximum,” “33% maximum” and “50% maximum” scenarios respectively). A logit model treats 100% as its maximum value. A fraction of 100% is made to be the maximum e-retail market share by dividing the e-retail equilibrium market share before 2017 by that fraction, performing the forecast, and then multiplying the predicted values by the same fraction.

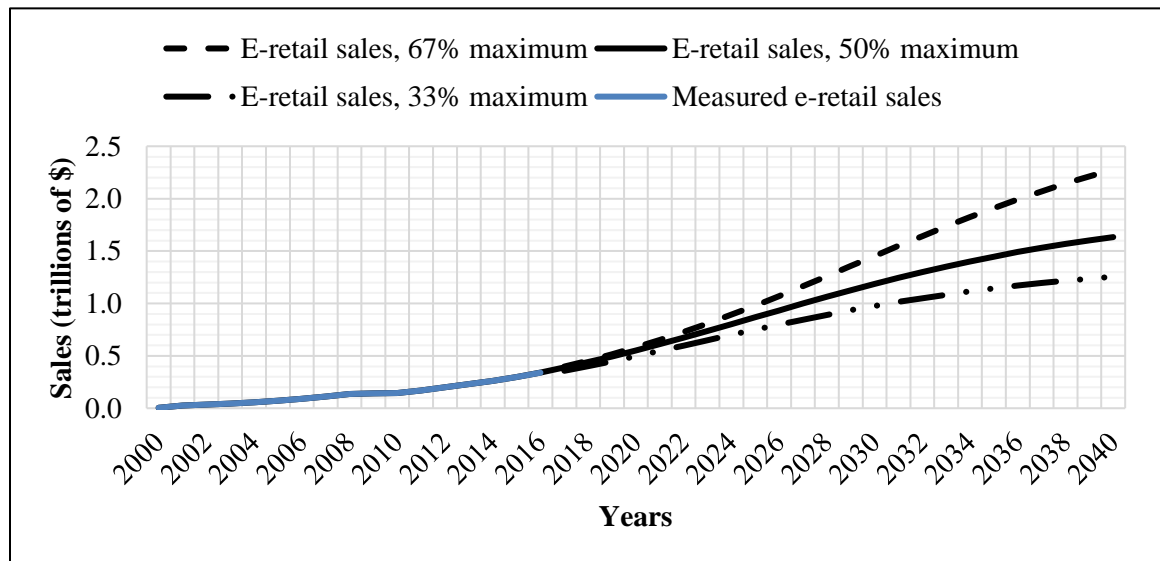
The 33% maximum scenario forecasts an e-retail market share of 23% in 2030 and 30% in 2040, which represent growth of 50% and 120% respectively. Figure 65 below depicts the forecasted market share for e-retail through 2040 for each scenario. It suggests robust long-term growth that may only start to approach equilibrium around the horizon year of 2040.



**Figure 65. Measured and forecasted e-retail market share.**

Total sales volume of U.S. retail in 2016 was \$4.8 trillion. Domestic retail sales are expected to grow to approximately \$5.7 trillion in constant dollars by 2040. E-retail sales

in 2016 were \$390 billion. Growth forecasted by the ‘50% maximum’ scenario predicts 328% growth in e-retail sales by 2030, which would produce \$1.45 trillion in domestic e-retail sales. Under the same scenario, e-retail sales could be as high as \$2.28 trillion by 2040.



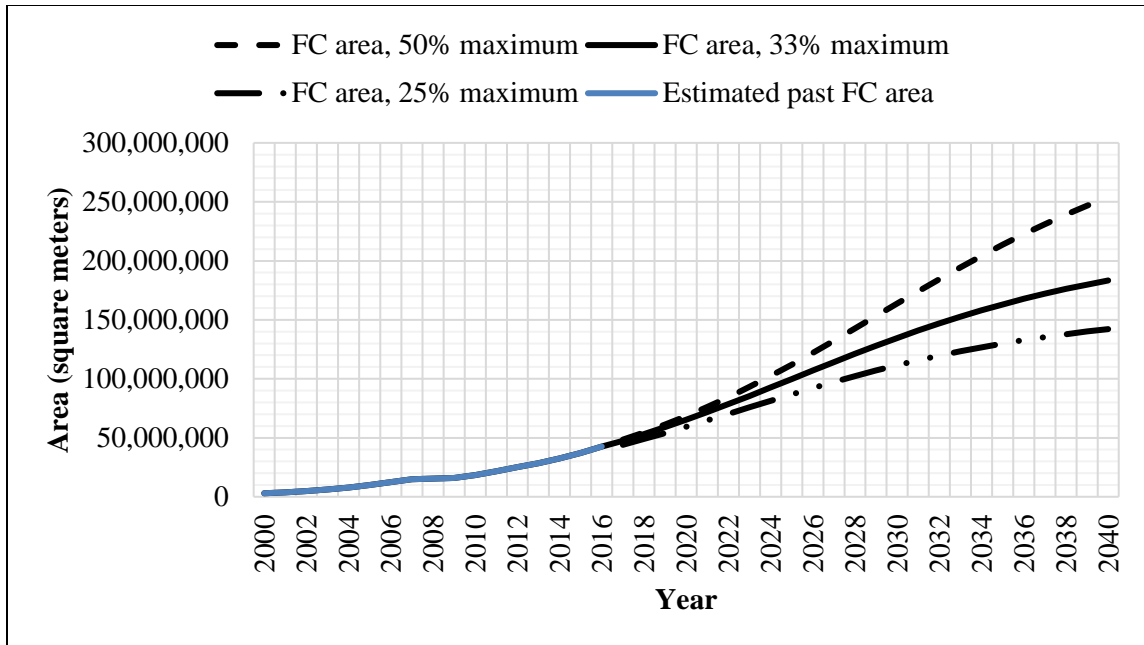
**Figure 66. Forecasts for e-retail sales volume through 2040.**

#### 8.4.3 Land Use

E-fulfillment’s future land use needs are estimated as a function of the sales volume forecasts and the warehouse space needed on average to support a dollar of e-retail sales. Warehouse space per dollar of e-retail sales is derived from Amazon’s 2016 U.S. fulfillment network since Amazon represents the most advanced large e-fulfillment network. Domestic FC floor area reported in Amazon’s 2016 annual report is divided by its domestic sales revenue to estimate a ratio of warehouse area per dollar of sales (Amazon 2016). The resulting ratio is \$9,155 per square meter of FC space. It is assumed that this

revenue will remain roughly constant over time. Then, the ratio is multiplied by the expected e-retail sales volume to estimate national e-fulfillment square footage.

This also allows for an estimate of total FC floor area in 2016 of 43 million square meters, which suggests that the sample of FCs in Analysis 1 (Location Model) encompasses 28% of all FC floor space in the United States. Demand for industrial land to serve e-fulfillment will influence regions' land use profile with an overall increase in warehouse space because e-retail consumes about three times as much industrial land per sales volume as B&M retail (Whelan 2016). The forecasts reinforce the belief that the country is still at the beginning of dramatic increase in FC floor area. In the '33% maximum' scenario, the U.S. is expected to have 53% more FC area in 2020 than in 2016, and 331% more FC area in 2040 than in 2016. This scenario suggests some 183 square kilometers of FCs nationwide, larger than three Mannhattans. Figure 67 depicts FC area forecasted through 2040.



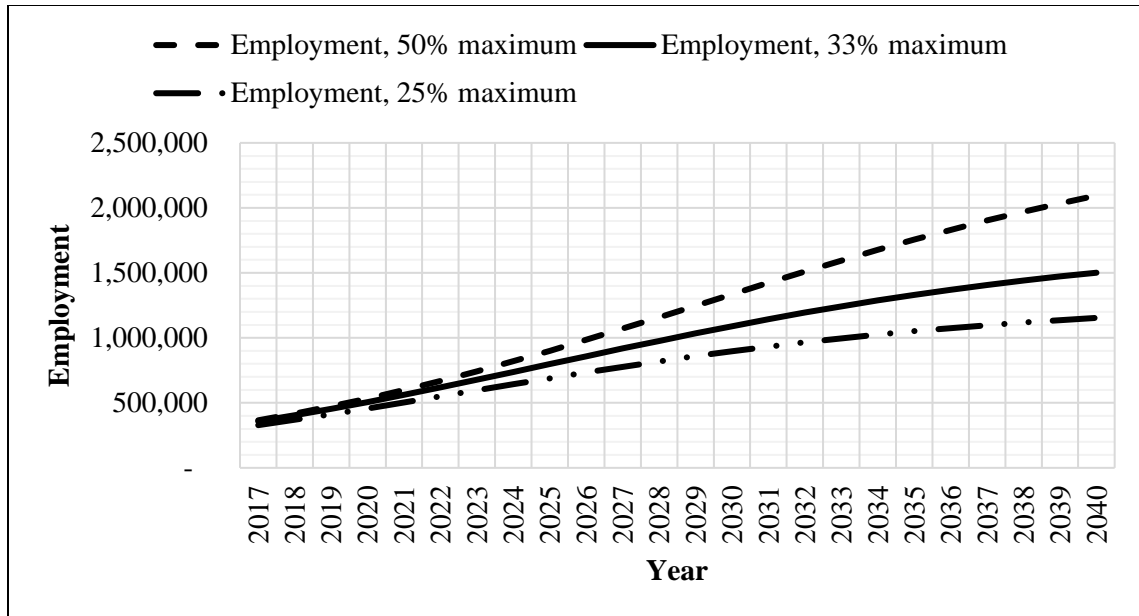
**Figure 67. Forecasted growth in American FC area.**

Despite the forecasts for fast growth of FC space, there are reasons to assess its development impacts conservatively. First, gains in FC space may be compensated in some regions by losses in DC space or in B&M retail space (e.g., shopping malls), leading as much to redevelopment and repurposing as new, greenfield development. Secondly, robotization of FCs can increase inventory capacity by about 50% holding FC size constant by allowing reconfigurations and narrower aisles (Kim 2016). It is also conceivable that there may exist interactions, positive and negative, among e-retailers in a region. More research is needed to assess whether growth of a large e-retailer like Amazon in a region improves, impinges on or otherwise influences smaller e-retailers' ability to implant logistics operations in that region. Therefore, e-retail's growth may result in fewer new FCs than the raw forecasts suggest.

#### 8.4.4 *Employment*

FC employment is also forecast via Amazon's statistics reported in its 2016 annual report (Amazon 2016). Amazon reports the number of employees in its domestic FCs, which is divided by its sales to estimate a ratio of employees to sales. The ratio is 9.19E-07 logistics employees per dollar sales (or \$1,087,896 / logistics employee). Logistics employment is forecast for scenarios with a maximum e-retail market share of one third, one half, and two thirds. Each scenario is further split into a low-automation future that assumes that the employee-to-sales ratio will remain constant, and a high-automation future, that assumes that the employee-to-sales ratio will be divided by four, based on the finding that Amazon's Kiva robots can increase employees' productivity by 400% (Rotman 2013). The high-automation future appears likely since Amazon and other e-retailers are already adopting automation.

Employee growth is much less precipitous than sales growth if automation continues to replace FC labor. There are an estimated 311 thousand American FC employees as of 2016. The '33% maximum' scenario with high-automation scenarios foresee this number increasing by just 20% by 2040, which is not comparable with sales volume growth of 381%. The low-automation scenarios produce four times the employment of the equivalent high-automation scenarios, as visible by comparing Figure 68 (low automation) with Figure 69 (high automation). Automation hamstring the FC jobs outlook.



**Figure 68. Forecasted employment in American FCs (low automation).**



**Figure 69. Forecasted employment in American FCs (high automation).**

#### 8.4.5 *Surface Transportation*

E-fulfillment's impact on the surface transportation network is difficult to quantify because of insufficient freight flow data. Without quantifying today's e-fulfillment flows, it is difficult to forecast future states. Therefore, the dissertation does not attempt to quantify an air or ground freight impact attributable to e-fulfillment, but instead draws two broad lessons. The first lesson relates to location. The regions that are most suitable to e-fulfillment broadly are likely to experience the greatest mail or cargo related to it for both surface and air transportation. This includes airports in the regions of New York, NY; Chicago, IL; eastern Pennsylvania; Indianapolis, IN; Columbus, OH; Louisville, KY; Cincinnati, OH; Atlanta, GA; Charlotte, NC; Tampa, FL; Dallas, TX; Houston, TX; Phoenix, AZ; Los Angeles, CA; the Bay Area (CA); and Seattle, WA among others. The second lesson relates to scale. Transportation is likely to grow less than sales because financial imperatives will force e-retailers to curb movement distance and use of expensive modes. Moreover, economies of scale will help e-retailers realize these transportation savings. Given that sales are forecasted to grow by between 1,165% and 610% by 2040, transportation ton-mile growth over the same period could be somewhat less while concentrating in the regions containing FCs and customers.

### **8.5 Future Research**

Many results of the dissertation raise new research questions. They relate both to other influences on FC location choice and logistics network operations, as well as to improvements to airports' planning processes. Key research areas meriting additional attention are described in the following subsections.



*8.5.1 Do e-retailers' logistics strategies and networks' size affect the importance that individual facility managers assign to airports and integrator air hubs?*

Answering this question will reveal if the role of airports is likely to remain constant as e-retailers grow. Results of the location model and shipper survey diverge on the importance of air connectivity and business-friendly regulations to e-retailers. The difference between stated and revealed preferences may explain some of the divergence. Nonetheless, the firms represented in the location model and survey also differ in ways that could partially explain the divergence, especially since Amazon warehouses did not respond to the shipper survey. Amazon's absence is serious because Amazon operates an e-fulfillment network that is orders of magnitude larger than its nearest competitor, which gives it much greater access to scale economies. Amazon's scale and the existence of Prime Air could make integrators' networks less important in warehouse location choice than for smaller e-retailers, and it begs the question of how an e-retailer's scale affects its fulfillment network and FC location choice.

It may be difficult to determine how e-retail size affects logistics because of Amazon's operational opacity. In its place, researchers can study foreign e-retailers of similar scale (e.g., Alibaba), or 3PLs conducting large-scale operations serving many e-retailers. Additionally, as large B&M retailers like Walmart and Target grow into the e-retail space, researchers can examine how they leverage their large B&M retail distribution networks for e-fulfillment.

### *8.5.2 Why do regional expenses influence FC location less than DC location?*

DC managers report that labor and land costs more heavily influence their operations and location choice than do their e-fulfillment counterparts. Identifying the reason for the discrepancy could help airports and localities seeking to attract e-retail logistics to allocate their incentives most efficiently. The difference between the sales channels may reflect a new industry's prioritization of long-term market share over short-term profits. E-retailers may also recognize transportation as generating a larger proportion of logistics costs, leading them to emphasize transportation costs over warehouse costs.

### *8.5.3 What strategies should local and state governments employ to attract e-fulfillment activity?*

Many factors influencing e-retail logistics are regional and therefore beyond airport staff's control. The question for airport staffs is if they can wield the factors within their influence to attract e-retail cargo by promoting regional e-fulfillment activity. For example, it is important to know whether provision of industrial land can attract enough FCs to justify the cost. Researchers can also investigate the effectiveness of strategies to attract integrator air hubs, logistics training programs at local technical colleges, and coordination of near-airport zoning to preserve industrial sites. The feasibility and success of these policies in attracting e-fulfillment activity can directly influence airports' business development.

#### *8.5.4 Can airport planners induce shippers to participate in planning?*

Shippers are reticent to share information about their operations even though it can help airport planners understand their cargo customers' needs. If planners can effectively reassure shippers as to the confidentiality of their information and utility of their participation, they might gain valuable knowledge of logistics trends and operations. Strategies to investigate include data protection measures, communication around data safeguards and benefits of participation, streamlining participation, and development of trust relationships. The answer may raise the quality of information available to planners.

#### *8.5.5 Which freight community members should participate in airport planning to adequately understand e-fulfillment?*

When shippers and carriers do not participate in airport planning, planners have sometimes solicited the broader freight community to describe air cargo and e-fulfillment trends. Real estate brokers, integrators, 3PLs and others may collaborate with e-retailers sufficiently to understand the sector's trends. Past research has not identified these participants' comparative value to the planning process, the planning steps to which each participant can best contribute, and strategies to increase their participation.

## CHAPTER 9. CONCLUSIONS

### 9.1 Introduction

This dissertation is an investigation of effects of e-fulfillment growth on airports and regional development. E-retail's rapid expansion has reconfigured logistics networks, altered retail transportation needs, and transformed location choice criteria. Consequently, e-retail is invigorating commercial real estate markets and multiplying air cargo demand at a selection of large, medium, and small airports. This dissertation has reported a three-pronged analysis to understand geographic trends in e-fulfillment, associations with airport and regional traits, and airports' planning for e-fulfillment. The analysis results facilitate preparations by planners for e-fulfillment. Specifically, the study is intended to provide guidance to urban and airport planners on the relevant effects of e-fulfillment as well as appropriate planning responses. In this chapter, specific guidance is provided for planners at airports, departments of transportation, municipal zoning departments, and economic development agencies.

### 9.2 Major Results

**FCs spatially concentrate more than DCs at national and regional scales.** E-fulfillment today is geographically concentrated, and many of the primary clusters correspond with airport regions. Approximately 22% of e-fulfillment capacity is within 10 km of one of the 127 busiest cargo airports in the U.S., a proportion that is over a thousand times higher than would be expected if FCs were evenly distributed over the contiguous U.S.'s land mass. This incredible concentration does not only or even primarily result from

e-fulfillment's need for air cargo. Customer proximity, locations of industrial real estate, access to surface transportation infrastructure, and other factors all play a major role in attracting FCs to airport regions.

**FC managers value access to air transport much more than DC managers.** The regions with the greatest concentrations of e-fulfillment activity frequently also contain integrator air hubs or are within an overnight drive of the country's largest consumer markets. FC managers value airport proximity and air transportation much more than DC managers, and these preferences reflect in location choice. Theory, the location model results, and survey and interview results all corroborate the existence of a moderately close relationship between airports and e-fulfillment activity. E-retailers favor airport regions because they employ integrators and the postal service for outbound shipments, and location in these regions allows for fast and economical shipments. The fact that most shipments move by ground does not negate the benefit of having convenient air transport available when it is needed, nor of being centrally located in integrators' networks.

**Retailers of both sales channels exhibit great strategic diversity.** Neither e-retailers nor B&M retailers are monolithic. Warehouse location exhibits patterns as a function of sales channel, even while other factors also affect the configuration of logistics networks. Retailers' size, ability to generate economies of scale, product characteristics, customer expectations, customer locations, business and logistics strategies, taxes, and regulations all shape the distribution network in ways outside of this dissertation's scope. The reader should remember this caveat when applying research results to a specific firm. The results are most accurate in aggregate because individual retailers' characteristics may differentiate them from typical patterns.

**E-fulfillment is starting to affect secondary and tertiary logistics regions.** As e-fulfillment grows, its effects are becoming more widespread. It remains true that the largest air cargo effects of e-fulfillment are felt at integrator air hubs and large international gateways. At the same time, e-retailers are building new FCs and assigning smaller geographic areas of responsibility to each. The new FCs increase e-retailers' ease of access to the average customer and widely disperse the regional effects of e-fulfillment. E-fulfillment's decentralization explains why many medium-sized cargo airports have recently seen growth in e-fulfillment cargo. Over the medium-term, e-fulfillment decentralization is likely to continue as e-retailers' growing volume allows them to sustain multiple forward inventory locations. E-fulfillment decentralization also facilitates air shipments through medium-sized airports, particularly air shipments related to Prime Air. Amazon's scale allows it to operate more facilities in more regions than its competitors even as the industry follows Amazon's decentralizing lead. Experts disagree whether ever-increasing air cargo demand will accompany e-fulfillment decentralization, or if at some point the industry will learn to manage its forward inventories well enough to reduce domestic air shipments. Internationally, the absence of alternative ground modes may provide air carriers more reliable air cargo demand.

**E-fulfillment is gaining prominence in airport plans.** Airport planners are recognizing e-fulfillment's impact and incorporating the trend into plans. Before 2014, references to e-fulfillment in airport plans were rare and primarily confined to near-airport real estate development. References to e-fulfillment in early plans had little impact on data collection or forecasting. Airport planners' interest in e-fulfillment has risen dramatically since 2014. Amazon's creation of Prime Air in 2016 also raised e-fulfillment's profile at

its host airports. Among the sample, the airports whose staff and / or planning documents are most attuned to e-fulfillment either already host Prime Air, have major Amazon FCs in their region, or are within a few hours' drive of very large consumer concentrations. Nonetheless, there has not been consensus among airport planners about how to plan for e-fulfillment from the perspective of data, forecasting methods, or business development. Some airport planners actively seek to attract e-retail cargo either through initiatives documented in the airport master plan or separate regional development plans, while aspiring to accommodate rather than influence related air cargo needs. Other airport planners do not distinguish e-fulfillment as a cargo trend, focusing instead on general trends in cargo generation.

**Airport planners are exploring innovative data sources to compensate for inadequacies of freight movement data related to e-fulfillment.** Planners at all airports studied use quantitative models to forecast cargo demand, and most generate multiple scenarios. However, models' data inputs and specifications diverge widely. Very little data is available to planners on e-fulfillment dynamics, so even airport planners that view e-fulfillment as a major influence on cargo activity rarely quantify its impact. Planners at a small number of airports supplement quantitative models with qualitative information based on freight community interviews. Qualitative data help either to create scenarios or to interpret forecasts.

### **9.3 Policy Recommendations**

Policy recommendations are divided into two sets, which are detailed in the following subsections. The first set applies to airport planners and is further subdivided

into three categories: forecasting air cargo demand, stimulating air cargo demand, and reducing airport-incurred risk. The second set of policy recommendations applies to planners specialized in land use, transportation, or economic development.

### *9.3.1 Recommendations for Airport Planners*

Recommendations for airports counteract the challenges of planning for e-retail as a category of air cargo demand with sparse data and unstable trends. Implementation steps vary as a function of organizational and local conditions. Some airport staffs are embedded in local governments, some are relatively autonomous authorities, and a few exist in privately operated airport corporations.

#### *9.3.1.1 Forecasting Cargo Demand*

Demand forecasting is a foundational planning step that allows planners to compare capacity with future needs. Nonetheless, data requirements and assumptions of each forecasting approach can undermine implementation. Airport activity forecasts are nearly always provisional, and e-fulfillment complicates the task of forecasting demand. As demonstrated in the chapter on airport planning benchmarking, carrier-reported cargo data is currently inadequate to understand e-retail's growing share of air cargo activity. Therefore, forecasters should consider the following actions to overcome data inadequacy.

**Forge relationships with shippers and carriers.** One of the greatest challenges to infrastructure planners studying e-retail is the unavailability of flow data for e-retail cargo. Data on cargo flows disaggregated by sales channel would allow planners to model the dynamics underpinning e-fulfillment and to fine-tune forecasts. In the absence of flow data,



airport planners should acquire substitute data on e-fulfillment. Relationships with carriers and shippers may provide airport planners with insights into operational trends, whether quantified or not. Carriers and shippers may be more inclined to disclose information if a relationship of trust already exists, airport planners guarantee non-disclosure, and planners illustrate planning's benefit to carrier operations.

**Include the freight community in regional transportation planning.** The freight community includes carriers, shippers, chambers of commerce, MPOs, industrial real estate developers, and industrial real estate brokers among others. The freight community can assist airport planners by compensating for gaps in quantitative cargo data and by describing e-fulfillment trends. These trends are very valuable because planners should align their forecasting models with the dynamics of cargo generation. The speed of e-fulfillment's evolution means that even the most knowledgeable members of the freight community have little predictive ability beyond a short time horizon. Moreover, airport staffs work through the regional transportation planning process to address the airports' landside connectivity. For instance, local governments and state DOTs designate truck routes on local and state roads respectively. If changes in road designation or enhancement of the roads' size or condition is required for improved airport access, airport staff will need to become involved in decision making in these organizations, as well as in the state DOT's and MPO's transportation planning processes. Depending on the truck routes used to access the airport, tollway authorities may also be involved.

**Select forecasting approaches that align with planning goals and airport conditions.** Inadequate data is not the only constraint to producing useful air cargo forecasts. The alignment between the forecasting approach, goals, and available data is also

essential. Each forecasting approach has limitations. The key to useful forecasting is to apply models intelligently with an understanding of what they capture, assume, and omit. Planners can disassemble cargo demand into separate aggregable forecasts for specific types of activity, such as domestic origin / destination, domestic connecting, and international origin / destination. Disassembling forecasts by cargo type allows the most accurate model for each type of cargo to be used, and the results summed. For example, econometric models or even market share analyses fit origin / destination forecasts better than connecting cargo since connecting cargo derives from air carrier networks rather than from the regional economy. Time series trend extrapolation may be more appropriate when relevant future conditions (e.g., population, economic activity) cannot be adequately forecasted and the nature of demand is roughly constant. Conversely, scenarios can better forecast connecting cargo demand because connecting volumes are most directly a function of air carrier decisions rather than regional economies. Carriers' network decisions often diverge from trends suggested by time series activity data and from regional economic development. Table 23 summarizes the opportunities and difficulties associated with air cargo forecasting approaches. Time series trend extrapolation has the simplest data requirements, although airports general lack the record of past e-retail cargo activity needed to execute it. Market share analysis is similarly handicapped by the lack of national estimates of e-retail cargo. Econometric models require more complex datasets and forecasts of relevant variables.

**Table 23. Assessment of forecasting approaches for e-retail cargo.**

	<b>Data difficulty</b>	<b>Forecasting difficulty</b>	<b>Forecasting usefulness</b>
Scenario	<b>Low:</b> Freight community interviews <b>Moderate:</b> Estimates of cargo generation by specific prospective activities	<b>Low</b>	Useful for preparing several scenarios for unpredictable phenomena
Time series trend extrapolation	<b>Moderate:</b> Past years' airport-level e-retail cargo data	<b>Low</b>	Useful for phenomena that are fundamentally stable
Market share analysis	<b>Moderate to high:</b> National forecasts and airport share	<b>Moderate:</b> Difficult to forecast airport share	Useful when trustworthy national or global forecasts exist and market share is stable
Regression-based econometric	<b>High:</b> Needs past data for many associated variables to calibrate models and forecast activity.	<b>Moderate:</b> Must forecast demographic and economic conditions	Useful if demographic and economic conditions are following stable trends and data is available

Several approaches and data types may be used to generate scenarios. Interviews with members of the regional freight community are one of the easiest types of data to obtain for scenario generation. Another approach is micro-scale analysis of cargo-generating activities, as performed for the LCK airport master plan. Air cargo generation is complicated in aggregate because of the multitude of forces operating on it. Micro-scale activity analysis allows demand to be disassembled to a scale at which it is comprehensible. Micro-scale activity analysis is most easily performed at small to medium-sized airports with a moderate number of cargo-generating firms and activities. It may also be easiest to perform when the airport maintains an owner-tenant relationship with cargo generators such as that provided by management of a nearby logistics park. Maintaining relationships with cargo generators can facilitate acquisition of data about their activities and prospective tenants.

A long-term solution for the collection of data on e-retail cargo will require coordination among carriers, airports, and the data-collecting agencies. Useful data for air cargo forecasting include statistics on airport-level e-retail cargo activity reported by airports, as well as flight or market cargo metrics reported by airlines. Frameworks for collecting data at both levels already exist since airports report statistics on air cargo (collected by airlines) to the FAA and Airports Council International – North America (ACI-NA), while air carrier report passenger and cargo activity through the Bureau of Transportation Statistics’ (BTS) monthly T-100 form. Data collection could occur voluntarily or by government mandate. Organizations like the International Air Transport Association (IATA) could both gather data in a voluntary approach and help mediate among airports, airlines, and end users of the data to broker compromise with data collection standards acceptable to all. ACI-NA is a natural spearhead for data collection since airport planning departments are one of the natural beneficiaries of improved data collection. A mandatory approach would likely be coordinated by BTS, housed within USDOT, or the U.S. Department of Commerce’s Commodity Flow Survey. For instance, changes to regulatory requirements could allow BTS to add a category describing shipper type to its T-100 form, allowing the identification of retailer shippers. The Commodity Flow Survey already collects shippers’ NAICS codes, although NAICS codes are insufficient to identify e-retailers independently based on results of the shipper survey in this dissertation. Both mandatory and voluntary improvements to data collection are likely to be difficult since they may entail changes to air carriers’ internal recordkeeping and may cause concern about the protection of business secrets and strategies by carriers and shippers.

#### 9.3.1.2 Stimulating Air Cargo Demand

Policy recommendations to stimulate air cargo demand are appropriate for airport staff that seek to influence shipper location and carrier networks. Many airport staffs desire greater airport activity, both to boost airport revenues and to promote regional development.

**Preserve airport access to industrial sites.** The location model and shipper survey revealed that e-retail shippers often value accessibility to an airport for domestic or international freight, especially an integrator air hub. FCs do not need to be adjacent to the airport when a short drive usually suffices, with 30 or 40 minutes as a very rough estimate of acceptable distance based on survey responses. Strategies to preserve industrial land near the airport necessarily differ as a function of regional conditions. Airports in regions with ample undeveloped land may require little or no concerted action to preserve industrial land. Staff at airports in regions with constrained land supplies should consider strategies as a function of regional conditions.

Low-development regions: Staff should consider buying land or coordinating with local zoning authorities to preserve industrial land near airports if the regions is trending towards medium-term build-out. Land zoned for commercial and industrial purposes is typically more appropriate around airports than residential land due to aircraft noise, particularly under runway approaches.

Middle-development regions: Staff should encourage local governments to preserve sufficient industrial land through zoning for long-term airport-related activities in regions nearing build-out. Suitable land for logistics includes parcels with noise-related

development restrictions due to airport proximity since logistics activity entails low-rise development that is unbothered by airport noise. Staff at several airports in medium-sized regions have acquired underutilized commercial or residential land near the airport to prevent incompatible development and preserve land for aviation-related uses.

High-development regions: The most difficult case is airports in regions that are already built out. Staff can either seek to provide industrial land near the airport, ease movement to more distant sites, or some combination of both strategies. Higher value-added or time-sensitive functions can occupy near-airport sites. Under-utilized sites near an airport may be acquired at a reasonable cost and developed by the airport authority or transferred to developers for industrial uses. To facilitate access to remote sites, the airport staff may collaborate with regional organizations, MPOs, and state DOTs to fund roadway widenings, truck-only toll lanes (TOTs), and even rail links.

**Be responsive to changing shipper and carrier needs.** Airport staff members interviewed for this dissertation explained that Prime Air's airport selection process was extremely fast, even for a carrier. More generally, decision making for private-sector logistics is more rapid than infrastructure planning. The speed of logistics transformation makes it unrealistic for airport planners to fully and accurately foresee the needs, timing, and associated conditions of cargo demand. Carriers or shippers may contact airport management considering new operations contingent on the airport staff's ability to meet needs for space, workforce, aircraft movement schedule, or fees. If the airport staff can respond quickly and effectively to these requests, the shippers or carriers may begin and sustain operations from the airport. Airport staff should weigh the requests' cost against their likely value to the airport and the region.

**Attract air cargo carriers, especially integrators.** The location model and shipper survey showed that many e-retailers gravitate towards regions with large customer bases and integrator air hubs. Consequently, an airport may attract logistics firms if it can spur an air carrier to open a cargo hub at the airport, even a small regional hub. Attracting a hub is a long-term strategy rather than a short-term one, and success is far from guaranteed. The academic literature identifies airport initiatives that appeal to air cargo carriers, including shortening transfer times (Ohashi et al. 2005), reducing customs delays (Gardiner, Humphreys, and Ison 2005), lowering operating costs (Ohashi et al. 2005), reducing congestion, lessening operational restrictions, upgrading landside connectivity (Gardiner, Humphreys, and Ison 2005), and enhancing infrastructure quality (Menon 2013; Yeo, Wang, and Chou 2013). Even in the best of circumstances, airport staff cannot affect regional factors, such as geographic centrality, weather (Huston and Butler 1991), and regional economics (Lee and Yang 2003), making this strategy inadvisable for airports in regions whose underlying traits are not otherwise attractive to air cargo carriers.

#### 9.3.1.3 Reducing Planning Risk

Airport leaders incur risk when they commit the airport to capital improvements requiring years of planning, design, and construction. All aspects of airport demand involve uncertainty, and some airport leaders have hamstrung their financial future by planning for overly optimistic demand projections. Decision making for megaprojects frequently demonstrates a systemic optimism bias (Flyvbjerg 2006). The risks incurred with optimistic demand projections are compounded for new, fast-changing phenomena like e-retail. Additionally, the airport staff interviewed explained the environment of highly uncertain demand for air cargo within which they operate. Therefore, airport leaders should

be cautious committing to capital investments related to e-fulfillment, not foregoing opportunities but rather deferring financial commitments as late as reasonable and maximizing their ability to re-evaluate decisions as new information becomes available.

**Increase plan updates.** E-fulfillment is evolving very quickly, which degrades forecasts' accuracy. No one, not even the e-retailers themselves, can foresee the ultimate structure of the industry because the technological and economic underpinnings are nebulous, and the industry's configuration is beyond any one organization's control. Planners should update air cargo plans frequently, either in whole or through auxiliary studies. Addenda allow for existing plans to be retrofitted for trends like e-fulfillment not originally considered in the master plan. The planners gather information about the topic under consideration, and estimate the direction and approximate magnitude of changes to previous forecasts, while also recommending any investments or policy changes that are appropriate. They should re-evaluate trends and examine deviations from forecasts, supplementing forecasts with new information and revising them if proven unreliable. Auxiliary studies need not be comprehensive since many elements will not have changed enough to require an interim update. Auxiliary studies have several advantages over replacing the entire master plan. Auxiliary studies are less costly than master plans, and they are even cheaper if the master plan included scenarios that have already recommended different actions depending on cargo volume. Scenarios can even build in triggers for specific actions or analysis to be activated based on the update's evaluation without having to re-do forecasts, infrastructure need assessment, and project evaluation. Auxiliary studies can also be completed more quickly than master plans, thereby minimizing the length of time during which airport staff is deprived of decision making guidance. Finally, auxiliary



studies are small enough to be conducted more or less continuously by a small planning staff in response to changes in conditions.

**Reduce risk and exposure.** Adaptive policymaking (APM) describes how decision makers can counteract vulnerabilities that may arise in the conditions for successful plan execution. To hedge risks, planners create options for policymakers to implement in the eventuality that uncertain risks occur (Kwakkel, Walker, and Marchau 2008). Hedging actions are built around flexibility since the ability to change future action or retrofit existing developments allows policymakers to counteract harmful trends (e.g., hub closure, flight reductions, or economic downturn). For example, some Canadian airport authorities hedge the risks of uncertain passenger demand by designing passenger terminals with movable dividers among waiting areas for domestic, U.S., and other international flights. Planners need not forecast each traffic type perfectly since the terminal layout is easily adjusted to accommodate changes in the demand profile. This flexibility built into facility design controls for forecasting inaccuracy. Planners can similarly design flexibility into physical infrastructure, plans, and policies. Planners should examine how each investment can serve airport needs in multiple scenarios through reconfiguration or repurposing. For instance, land for future airport infrastructure can be set aside in a location where it could serve airside cargo, passengers, landside airport-related activity, or some combination of the activity types as a function of eventual demand. Similarly, a new airside cargo terminal can be designed such that it can serve landside functions by sealing its airside connections if cargo traffic falls dramatically. These decisions relate to the ability of infrastructure to be maximally useful in multiple forecast scenarios and with multiple airport activity mixes.

Additionally, long-term spending commitments are riskier than short-term commitments. The recommendation to delay spending decisions related to e-retail air cargo derives from adaptive policymaking (APM), which “takes actions that might be needed right away and creates a framework for future actions that allows adaptations over time as knowledge of the future becomes available” (Kwakkel, Walker, and Marchau 2008). Airport leaders incur fewer risks whenever investments are phased and re-evaluated before each implementation step.

### *9.3.2 Recommendations for Urban Planners*

Recommendations for transportation planners, land use planners, and economic development planners are described in the following paragraphs.

#### *9.3.2.1 For Land Use Planners*

**Increase model sensitivity to changes in shipper location choice.** The dissertation results demonstrate that FCs follow a different logic in location choice than do DCs or other types of logistics facilities. The important regional characteristics in location choice differ between FCs and other types of logistics. To account for this change, land use models should be sensitive to the nuances in location choice that distinguish logistics activity types and sales channels. Accurate land use models are important since these results serve as inputs to transportation models as well.

**Maintain flexibility in the supply and location of industrial land.** E-retail is causing industrial land markets in many parts of the country to experience very high levels of demand, which incites developers to build new warehouses. If the supply of industrial

land is in the wrong places or is insufficient, developers must petition to rezone suitable parcels. Appropriate land use models can predict the locations of demand for industrial land with moderate accuracy, but the fast-changing nature of e-retail will inevitable produce divergences between forecasts and reality. Although specific land use tools are beyond this dissertation's scope, land use planners should plan for rezoning in a way that makes the comprehensive plan flexibly accommodate changes. One way to do this may be to study different development scenarios and pre-designate parcels that can be rezoned according to market demand without creating incompatibilities with neighboring uses.

#### 9.3.2.2 For Transportation Planners

**Consider the use of supply chain models for freight forecasting.** The results of the shipper survey revealed that e-retail shipments differ in mode and carrier choice from B&M retail shipments. Therefore, freight demand modelers should be aware of their models' ability to adapt their mode and carrier splits to e-retail's growing market share. One way to do this may be with supply chain models, which provide the benefits of granular decision making characteristic of agent-based models (Outwater et al. 2013). The granularity allows them to capture differences in decision making among activity types in a way that is impossible for simpler freight demand models. E-fulfillment's increasingly local and regional (as opposed to national) orientation will require that even these models be calibrated based on where the industry is going rather than where it has been.

**Collect e-retail freight movement data for use in freight demand models.** Travel demand models for passengers and cargo rest on a foundation of land use modeling. E-fulfillment's changes to land use trends and cargo patterns challenge calibrations of

freight demand models and underlying land use models. The dissertation results demonstrate that e-fulfillment freight patterns have mode splits, carrier splits, distance patterns, and destination distributions that differ from those in existing freight flow datasets that are primarily composed of non-retail and B&M retail freight. Updating datasets used to calibrate land use and freight demand models can help overcome this difficulty. Oversampling e-fulfillment may be necessary to obtain an adequate sample size for e-fulfillment.

**Prioritize short- and medium-term planning with frequent updates over infrequent long-range planning.** Interviews with logistics experts and airport staff delineated e-fulfillment's high rate of change and uncertainty surrounding future strategies. Long-term configurations of the logistics industry simply cannot be precisely foreseen. Even the most advanced models with the most complete data will produce major deviations from reality on an extended time horizon. E-retail's growth exacerbates the uncertainty. Accordingly, planners of all types should frequently update their forecasts and use short- to medium-term outputs for decision making and project selection whenever possible.

**Use scenario planning to address uncertainty.** The e-retail industry is subject to an exceptionally high degree of uncertainty. The leading logistics strategies and network configurations will doubtlessly change in ways that are hard for e-retailers to foresee, much less public-sector planners. Similarly to airport planners, transportation planners can benefit from scenario-based planning approaches because these approaches consider courses of action with multiple possible levels of demand for infrastructure. Scenario planning is a foundation for transportation planners to evaluate plans' sensitivity to unforeseen developments.

**Pursue regional planning approaches.** The dissertation's results demonstrate that e-fulfillment is multimodal and multi-scalar, frequently crossing planning and administrative boundaries. The locations where e-fulfillment networks cross from one mode or planning unit to another risk becoming bottlenecks if planning is uncoordinated. Coordination to prevent spatial discontinuities can encompass local governments, MPOs, state DOTs, transit agencies, airport authorities, and others transportation agencies. For example, landside airport access will be prominent since air cargo always involves surface transportation to and from the origin and destination airports. Facilitating landside airport access will hinge on coordination among the airport authority, the MPO, the state DOT, and local government around forecasting, project selection, funding, and the designation of truck routes.

#### 9.3.2.3 For Economic Development Planners

**Generate regional development strategies considering regional traits' attractiveness to e-retail.** The section on implications for regional development showed that regions' suitability for e-fulfillment differs from suitability for other kinds of retail logistics. Accordingly, economic development planners' relationship with e-fulfillment varies as a function of their region's and the logistics industry's interactions with the community's goals. Economic development planners' strategies for e-fulfillment should depend on whether e-fulfillment contributes to the community's development vision and be based on planners' understanding of the region's role in the larger economic system (Herlands et al. 2015). Planners should carefully consider the net benefits provided to their region by e-fulfillment growth before proposing incentives to attract firms. Economic development planners in all regions should remain aware of automation trends reducing

FCs' payrolls. Planners should also weight development's contribution to their locality's fiscal sustainability and tax base in considering whether a specific type of development should be pursued (Herlands et al. 2015). Economic development planners cannot easily change their region's fundamental traits to align them with e-fulfillment ideals. Thus, agencies in regions with low overall suitability are advised to recognize those limitations and pursue industries that align with their unique characteristics.

**Create the long-term conditions for e-fulfillment to succeed.** Among other responsibilities, economic development planners promote the conditions for the success and growth of base industries (i.e., those that export goods or services to other regions). E-fulfillment's ability to serve multiple regions from a single facility means that it often functions as a base industry. Incentives are a common short-term tactic to attract firms. Nonetheless, the American Planning Association recommends that economic development planners focus on creating the conditions of success for base industries rather than relying heavily on short-term incentives, which deplete the tax base when overused (Herlands et al. 2015). There is a limited set of conditions for e-fulfillment activity that communities are capable of influencing. Communities can make the regulatory environment friendlier to FCs, which the shipper survey showed to be the second most important regional trait for FC location. Similarly, training programs for medium-skill FC workers and high-skill robotics technicians can help e-retailers find the labor force that they require. Preserving industrial land in suitable locations and at a reasonable price may also help since "reserving land for basic industries is vitally important for economic growth" (Herlands et al. 2015). In addition to providing land, planners must also prepare for economic development by coordinating the transportation and utility infrastructure needed to develop parcels, while

also considering those parcels' proximity to the resources that the end users will require (Herlands et al. 2015). Thus, economic development planners may encounter more success in attracting FCs if they focus on fostering the conditions for e-fulfillment's success rather than on incentives.

### *9.3.3 A Way Ahead*

According to ACRP Report 143, "e-commerce...has had a significant impact on the growth of air freight" (Maynard et al. 2015). Logistics for e-commerce, or e-fulfillment, offers many airports an opportunity for moderate cargo growth and a few airports a chance for dramatic cargo growth. Already, e-commerce's growth has spurred the announcement of a new air cargo hub dedicated to Amazon at Cincinnati/Northern Kentucky International Airport (CVG). All the while, e-fulfillment has revitalized cargo demand at a set of international gateways and small to medium-sized domestic airports, and it has found its way into airport-related regional development plans in Atlanta, GA; Greensboro, NC; and Charlotte, NC among others. It is sensible to see the situation with clear eyes unclouded by exuberance. Planners should understand the uncertainties in forecasts related to e-fulfillment. Planners are advised to compare the relative risks of being unable to meet air cargo demand due to insufficient capacity against the risks of forecasted demand failing to materialize to support completed capital projects.

This dissertation has provided one of the most comprehensive appraisals of the relationship between e-fulfillment and airports. It is the most wide-ranging study to date in its combination of newly identified FC locations, warehouse survey results, logistics interviews, airport plan evaluations, and staff interviews at airports served by Amazon

Prime Air. It guides airport planning for e-retail cargo and recommends airport and urban planning enhancements.

Moving ahead, planners should review the state of the industry often, seek new data on e-fulfillment, build relationships with freight community members, maintain flexibility, and hedge risks. At most airports, e-fulfillment will remain one of many types of cargo activity competing for leaders' attention in a passenger-centric aviation world. Each of these other cargo types as well as passenger travel deserve their due in the planning process. Notwithstanding, this dissertation has made the case that e-fulfillment is growing, and that the attention and resources that airport planners allocate to understanding it should grow as well to a level roughly proportionate with its future activity contribution. The resources, particularly data, are beginning to be formed to help analysts understand airports' and regions' attractiveness to e-retailers. As the industry matures, the airports that become central to e-fulfillment networks should expect broader spillover into the regional logistics industry and the broader economy.



## **APPENDIX A. SHIPPER SURVEY**

The survey begins on the following page.

<p style="text-align: center;">PART A FACILITY OPERATIONS</p>
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Your facility's operations help us understand how transportation infrastructure and carriers support your operations. Please answer the following questions about your facility's products and sales channels.

1. **Retail logistics:** Is your facility involved in retail logistics, regardless of sales channel?  
(☐ Prefer not to answer)  
☐ Yes  
☐ No      If your facility is not involved in retail logistics, please briefly describe what your facility does instead, and skip to Part D:  
  
\_\_\_\_\_
  
2. **Functions:** Which of the following functions are applicable to your facility? (select all that apply)  
(☐ Prefer not to answer)  
☐ **Brick-and-mortar distribution** (inventory and transportation to physical stores)  
☐ **E-retail fulfillment** (inventory, order processing, and transportation to customers who made purchases through computers or mobile devices)  
☐ **E-retail returns** (processing of returned goods originally purchased through computers or mobile devices)  
☐ **Catalog distribution** (inventory and processing of orders received via printed catalog)  
☐ **Other(s):** \_\_\_\_\_
  
3. **E-retail sales volume:** Approximately what percentage of your outbound shipment volume is associated with e-retail sales? (☐ Prefer not to answer)  
☐ 0%      ☐ 1-24%      ☐ 25-49%      ☐ 51-74%      ☐ 75-99%      ☐ 100%
  
4. **Geographic focus:** Does your facility serve stores or customers in a specific part of the country?  
(☐ Prefer not to answer)  
☐ No  
☐ Yes      If yes, briefly describe your primary service area (e.g., "Arizona and California"):  
  
\_\_\_\_\_

**PART B**  
**WHAT DOES YOUR FACILITY NEED FROM A REGION?**

This section asks how important several regional characteristics are for your facility's operations. Please rate their importance for your current facility only (without regard for past facilities in which you have worked or other facilities in the company).

1. **Your region:** How important are the following state or regional characteristics for the success of your operations? (☐ Prefer not to answer)

	Not important	Somewhat important	Important	Very important
a. Low labor costs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. Low land costs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. Low business taxes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d. Business-friendly regulation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
e. Proximity to airport with cargo service	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
f. Proximity to Interstate Highway	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
g. Low roadway congestion	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
h. Proximity to seaport with cargo service	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
i. Ability to use freight rail	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
j. Proximity to suppliers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
k. Proximity to customers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
l. Other(s): _____				

2. **Airports & air carriers:** Do your operations utilize an airport or air carrier for outbound transportation either fully or partially? Please briefly specify which one(s) and by how much.  
(☐ Air transport does not play a role in facility operations)

Airports:

Air carriers:

3. **Air system:** Do the following matter to your business operations? (☐ Prefer not to answer)

	Not important	Somewhat important	Important	Very important
a. Presence of many air cargo carriers at nearby airport	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. 24-hour airport operations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. Proximity to air hub for express parcel carriers (e.g., FedEx / UPS / DHL)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d. Other(s): _____				

**PART C**  
**OUTBOUND TRANSPORTATION**

Distribution centers and fulfillment centers ship goods to stores and customers, which means that they interact with the broader transportation network. The following section asks how you move goods to and from your facility.

1. **Outbound shipment modes:** Outbound shipments are those that move from your facility to customers or stores. How often are the following modes used for all or a segment of outbound delivery routes? (☐ Prefer not to answer)

	Not at all	Rarely	Sometimes	Frequently
a. Air	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. Truckload ('TL')	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. Less than truckload ('LTL')	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d. Rail	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
e. Other(s): _____				

2. **Outbound shipment carriers:** How often are the following carriers used for outbound shipments? (☐ Prefer not to answer)

	Not at all	Rarely	Sometimes	Frequently
a. Trucks owned, leased, or operated by this facility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. Express parcel carriers (e.g., UPS, FedEx, DHL)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. U.S. Postal Service	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d. Other third-party logistics providers (e.g., C.H. Robinson)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
e. Other(s): _____				

*Questions 10-13 only apply to facilities that process at least some e-retail shipments.  
Please skip to Part D if your facility does not process any e-retail shipments.*

3. **Next-day deliveries:** What percentage of your e-retail shipments require next-day delivery? (☐ Prefer not to answer)  
☐ 0%      ☐ 1-24%      ☐ 25-49%      ☐ 51-74%      ☐ 75-99%      ☐ 100%
4. **Next-day delivery schedule:** By what time must your e-retail packages be transferred to the carrier to arrive by the next day (i.e. "drop-off time")? \_\_\_\_\_ PM
5. **Next-day delivery modes:** What percentage of next-day deliveries are transported by air? (☐ Prefer not to answer)  
☐ 0%      ☐ 1-24%      ☐ 25-49%      ☐ 51-74%      ☐ 75-99%      ☐ 100%
6. **Product air deliveries:** Excluding next-day deliveries, which of the following products are generally delivered by air? (select all that apply) (☐ Prefer not to answer)  
☐ None  
☐ Temperature-controlled goods  
☐ High value-to-weight goods (e.g., electronics, jewelry, apparel)  
☐ International deliveries

**PART D**  
**CONTACT INFORMATION**

This section lets you provide additional comments and optionally your contact information.

1. If the survey has omitted important information about your facility, operations, region, or logistics strategies, or if you have other comments, please write them here. You may also enclose additional comments with the survey response, or contact me electronically.

2.

Comments:

3. Your job title or function: \_\_\_\_\_

4. Your name (☐ I prefer to remain anonymous): \_\_\_\_\_

email address (☐ I prefer to remain anonymous): \_\_\_\_\_

phone number (☐ I prefer to remain anonymous): \_\_\_\_\_

5. May I contact you if there are follow-up questions?

☐ Yes

☐ No

6. Does your facility support [company name here]? (☐ Prefer not to answer)

☐ Yes

☐ No      If no, which company does your facility support?

\_\_\_\_\_

7. Would you like to receive an electronic copy of the final report? If so, please provide an email address above.

☐ Yes

☐ No

***Thank you very much for your participation! Please send us the survey in the pre-paid envelope.***

## APPENDIX B. SELECTION OF AIRPORTS FOR DOCUMENT REVIEW

**Table 24. Selection of candidate airports.**

<b>Airport</b>	<b>Large Regional FC Presence?</b>	<b>Cargo Enplanement</b>	<b>Known E-fulfillment Strategy</b>	<b>Air Integrator air hubs</b>	<b>Other Considerations</b>	<b>Decision: Select as Candidate?</b>
AFW	Yes	High		FedEx	Privately owned cargo airport	Yes
ATL	Yes	High	Yes			Yes
BDL	Yes			UPS		Yes
BNA	Yes					No
BOS		High				No
BWI	Yes					No
CAE	Yes			UPS	Growing e-retail around closed UPS hub	Yes
CHA	Yes					No
CLT	Yes					No
CMH	Yes					No
CVG	Yes	High		DHL	Slated for major Amazon construction.	Yes
DAL	Yes					No
DEN		High				No
DFW	Yes	High		UPS		Yes
DTW		High				No
EWR		High		FedEx	Major FedEx hub	Yes

<b>Airport</b>	<b>Large Regional FC Presence?</b>	<b>Cargo Enplanement</b>	<b>Known E-fulfillment Strategy</b>	<b>Air Integrator air hubs</b>	<b>Other Considerations</b>	<b>Decision: Select as Candidate?</b>
GSO			Yes	FedEx	Aerotropolis plan prepared by Kasarda	Yes
IAD		High				No
IAH		High				No
IND	Yes	High		FedEx	IND AeroVision is a planning process to promote development within 8 km of airport. Airport has land use agreements with surrounding towns.	Yes
JAX	Yes					No
JFK		High			One of the largest gateway airports	Yes
LAX		High			Large gateway airport	Yes
LCK	Yes	High			Dedicated cargo airport	Yes
MCO	Yes	High				Yes
MDT	Yes					No
MDW	Yes					No
MEM		High		FedEx	Largest FedEx hub	Yes
MIA		High		FedEx & UPS		Yes
MKE	Yes					No
MSP	Yes	High				Yes
OAK		High		FedEx		Yes
ONT	Yes	High				Yes
ORD	Yes	High				Yes
PDX		High				No
PHL		High		UPS		Yes
PHX	Yes	High				Yes
RFD		High	Yes	UPS	Growing Prime Air (Amazon) hub	Yes

<b>Airport</b>	<b>Large Regional FC Presence?</b>	<b>Cargo Enplanement</b>	<b>Known E-fulfillment Strategy</b>	<b>Air Integrator air hubs</b>	<b>Other Considerations</b>	<b>Decision: Select as Candidate?</b>
RIC	Yes					No
SAN		High				No
SAT	Yes					No
SDF	Yes	High		UPS	Largest UPS hub	Yes
SEA	Yes	High				Yes
SEA		High				No
SFO		High				No
SLC	Yes	High				Yes
STL	Yes					No
TOL	Yes					No
TPA	Yes					No



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